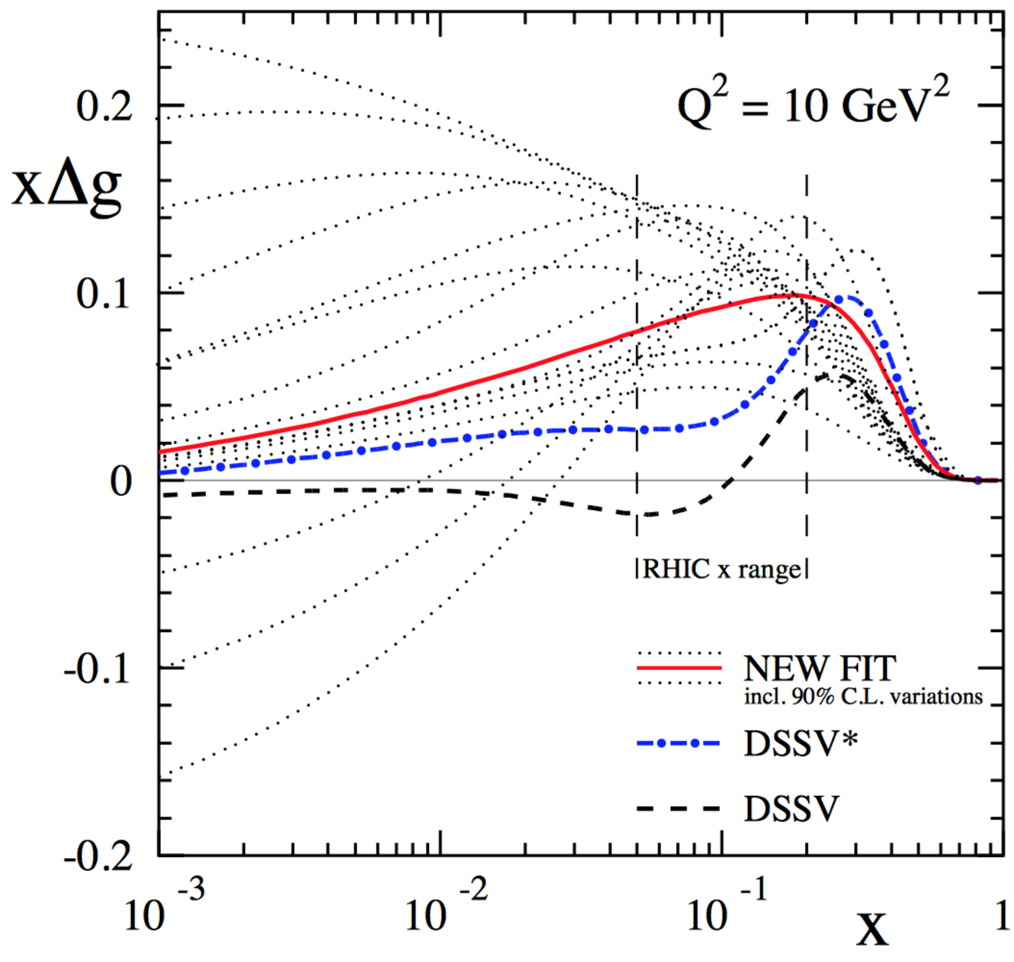
Measuring the Gluon Spin Distribution at Small-x

Mickey Chiu

BROOKHAVEN NATIONAL LABORATORY

Latest DSSV



- Non-zero dG from 0.05-0.2!

Gyrating gluons

In the latest work, a group of theorists – Daniel de Florian, from the Aires University in Argentina, and colleagues – analysed several years' worth of collision data from RHIC's STAR and PHENIX experiments. De Florian and colleagues have now studied data collected up until 2009, and have compared those data with a theoretical model they have developed that predicts the likely spin direction of gluons carrying a certain fraction of the momentum involved in the proton collisions.

The researchers discovered, in contrast to a null result they obtained using fewer data five years ago, that gluon spin does tend to line up with that of the protons, rather than against it. In fact, they estimate that gluons could supply as much as half of a proton's spin. "This is the first evidence t

contribution to prot

Tübingen Universi

grounds, gluons ou

neutrons.

st!

hare this

- E-mail to a friend
- StumbleUpon
- Twitter
- Facebook
- CiteUlike

SHARE

- 2003
- 2002
- 2001
- 2000
- 1999
- 1998
- 1997

13 comments

Add your comments on this article

1 **M. Asghar** Jul 12, 2014 12:17 PM

QCD complexicity with a dilemma

The possible contribution to the proton spin from the non-ablian gluons(strong interaction bosons of spin 1), its quarks and their orbital angular momentum shows the complexicity of the QCD. However, here one is faced with a dilemma: the proton's magnetic momemt is completely taken care of by the spin of its three quarks!

Reply to this comment | Offensive? Unsuitable? Notify Editor

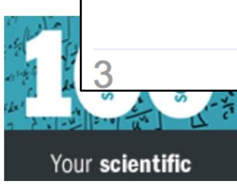
2 **dcasimir** Jul 14, 2014 5:09 PM

Germany 1 Argentina 0

A Germany Argentina collaboration?

Reply to this comment | Offensive? Unsuitable? Notify Editor

3 **mageshp** **why?**



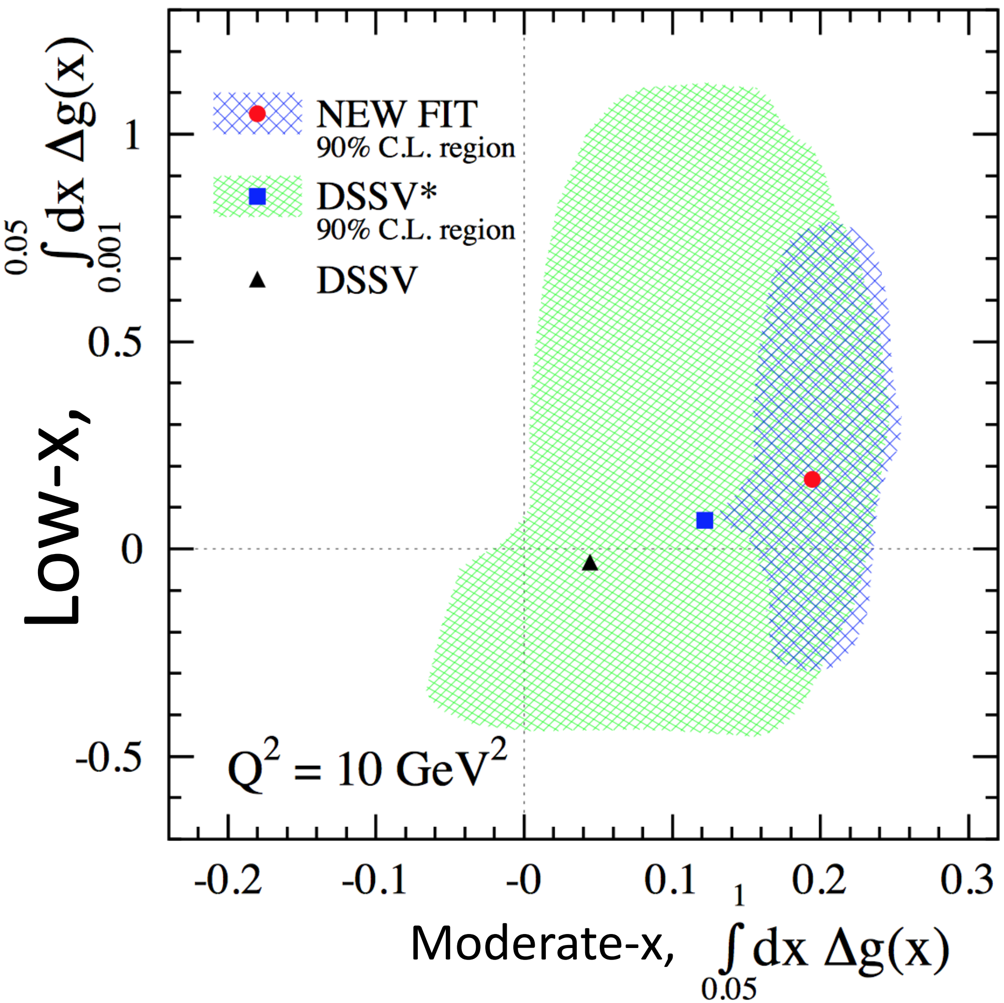
quarks – with two quarks spinning in the opposite direction to the third. But a series of experiments found that the quark spins contributed only a small fraction to the nucleon spins, leading to what

Upgrade Programme

ESRF

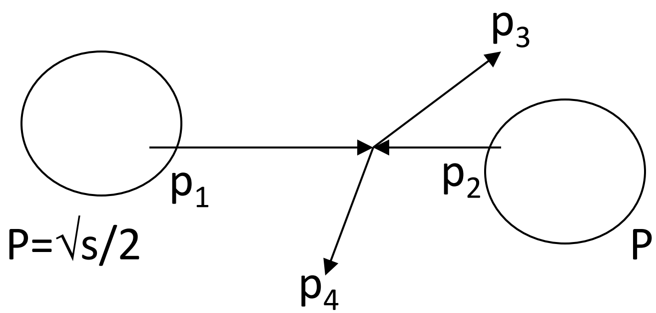
Jul 04, 2014

Large Uncertainty in total ΔG



- Lots of gluons at low-x, and thus can contribute significantly even if Δg(x) is small.

2→2 Hard Scattering (LO)



Simply Elastic Scattering!

Initial State:
$$p_1 = (x_1 P, 0, 0, x_1 P)$$
$$p_2 = (x_2 P, 0, 0, -x_2 P)$$

Final State:
$$p_3 = (E_3, p_T, p_{3,z})$$
$$p_4 = (E_4, -p_T, p_{4,z})$$

$$p_z = m_T \sinh y$$
$$E = m_T \cosh y$$

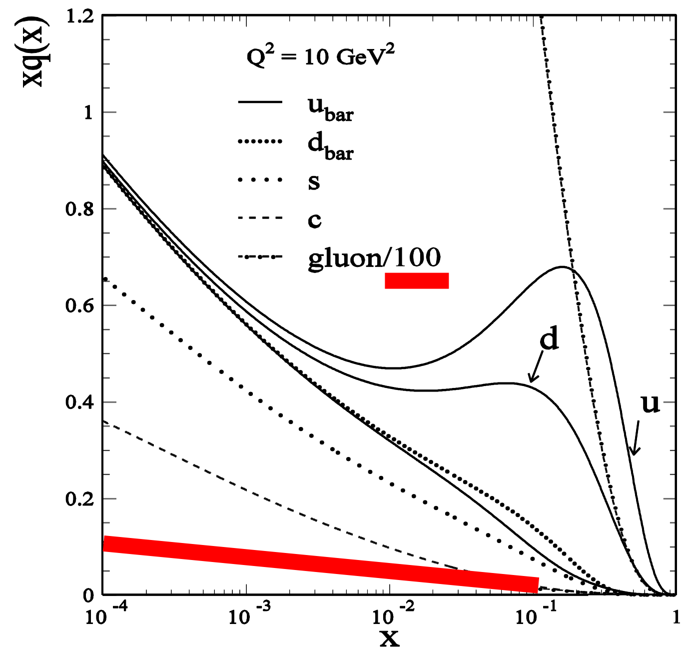
$$(x_1 - x_2)P = E_{3,z} + E_{4,z} = \frac{m_T}{2}(e^{y_3} - e^{-y_3} + e^{y_4} - e^{-y_4})$$
$$x_1 = \frac{m_T}{\sqrt{s}}(e^{y_3} + e^{y_4})$$
$$(x_1 + x_2)P = p_{3,z} + p_{4,z} = \frac{m_T}{2}(e^{y_3} + e^{-y_3} + e^{y_4} + e^{-y_4})$$
$$x_2 = \frac{m_T}{\sqrt{s}}(e^{-y_3} + e^{-y_4})$$

Special Cases:

a. y_3 forward, y_4 mid-rapidity (MPC-EMC)
$$x_1 = \frac{m_T}{\sqrt{s}}(e^{y_3} + e^{y_4}) \qquad x_2 = \frac{m_T}{\sqrt{s}} e^{-y_4}$$

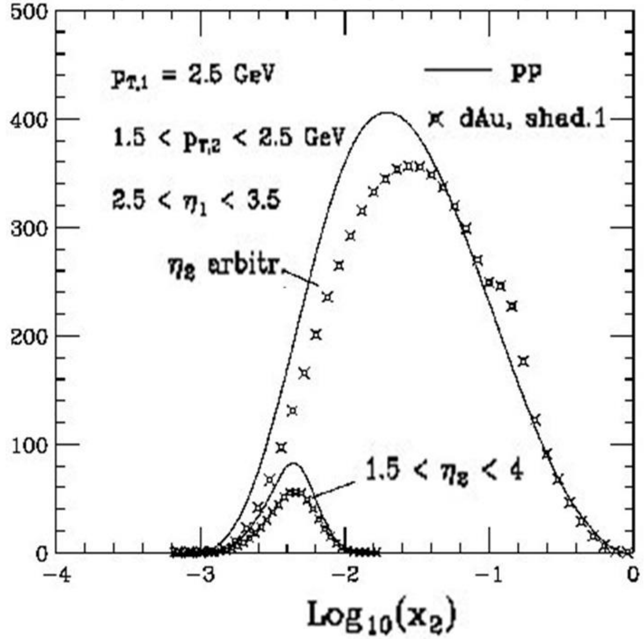
b. y_3, y_4 both forward (MPC-MPC)
$$x_1 = \frac{m_T}{\sqrt{s}}(e^{y_3} + e^{y_4}) \qquad x_2 \approx 0$$

a. y_3 forward, y_4 backwards (MPC.S-MPC.N)
$$x_1 \approx \frac{m_T}{\sqrt{s}} e^{y_3} \qquad x_2 \approx \frac{m_T}{\sqrt{s}} e^{-y_4}$$

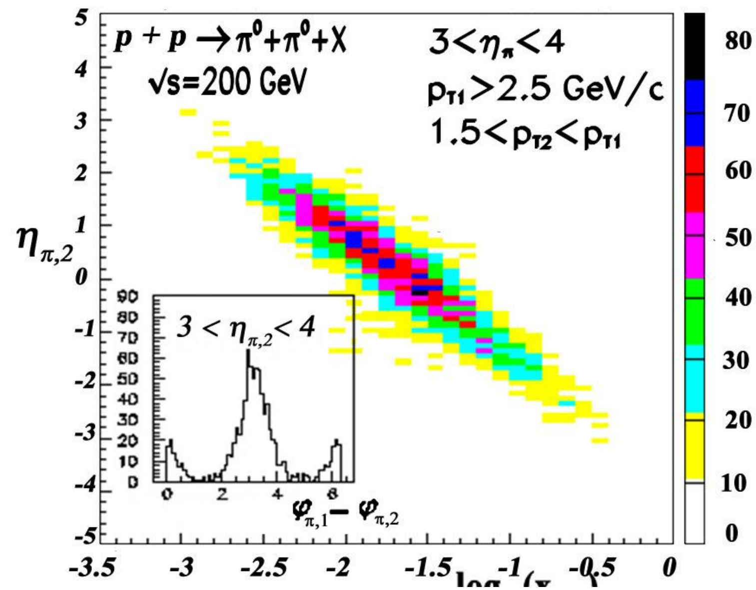


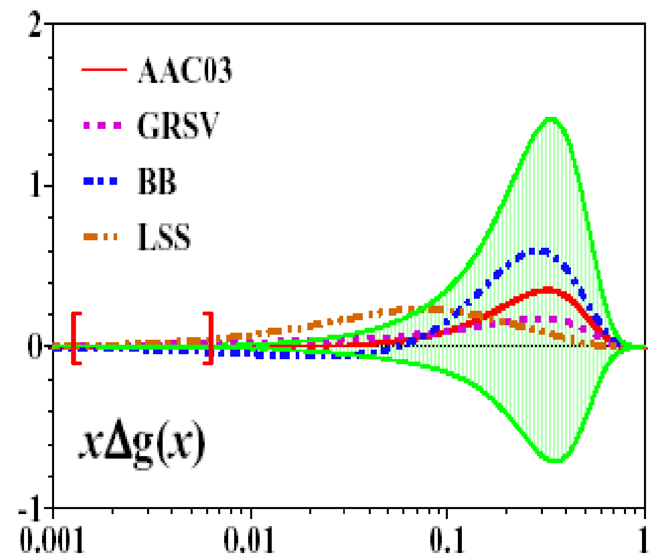
Di-Hadron A_{LL}: Constraining x values

Frankfurt, Guzey and Strikman,
J. Phys. G27 (2001) R23 [hep-ph/0010248].



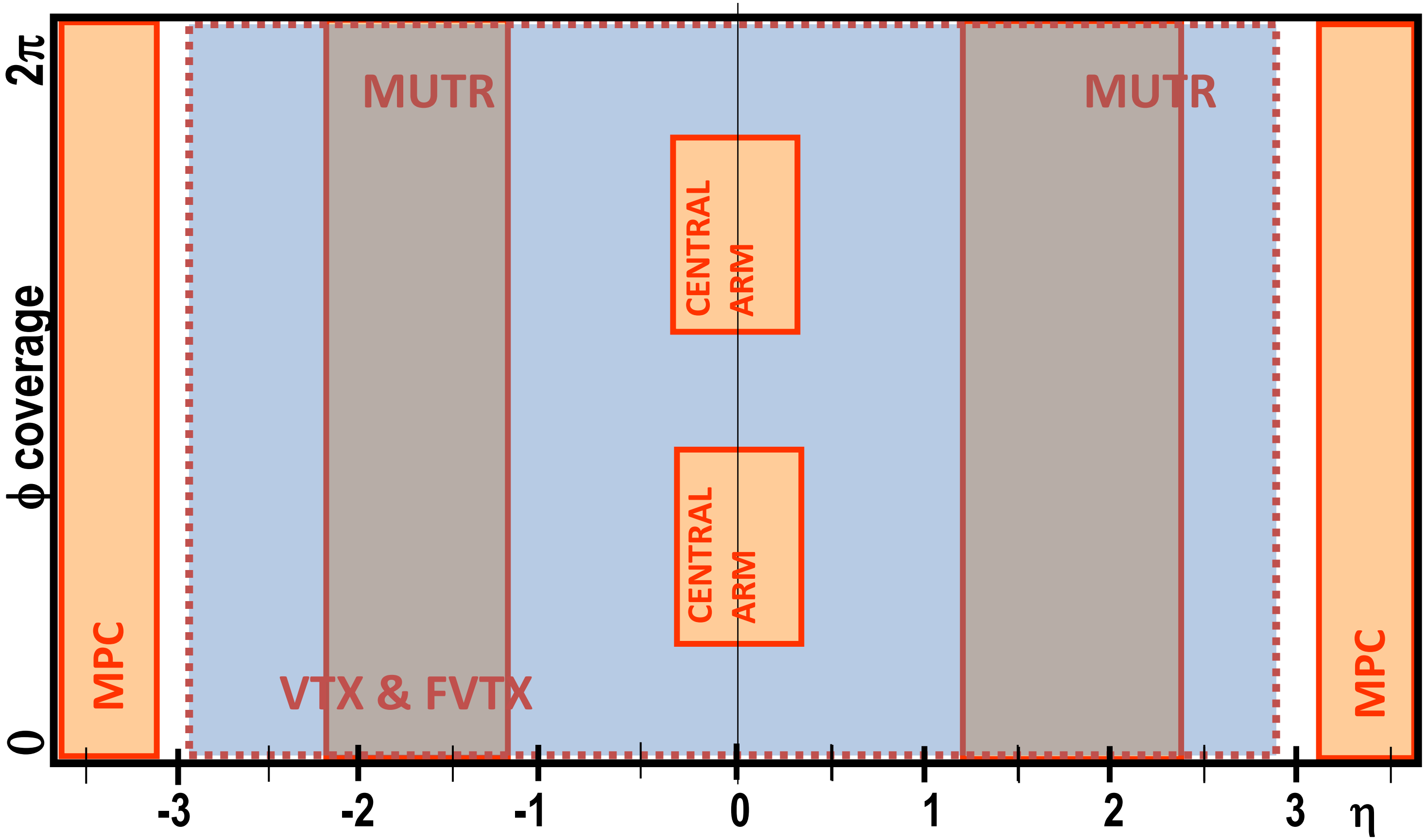
STAR Pythia Simulation





- constrain x value of gluon probed by high-x quark by *detection of second hadron* serving as jet surrogate.
- span broad pseudorapidity range for second hadron $\Rightarrow$ span broad range of x_{gluon}

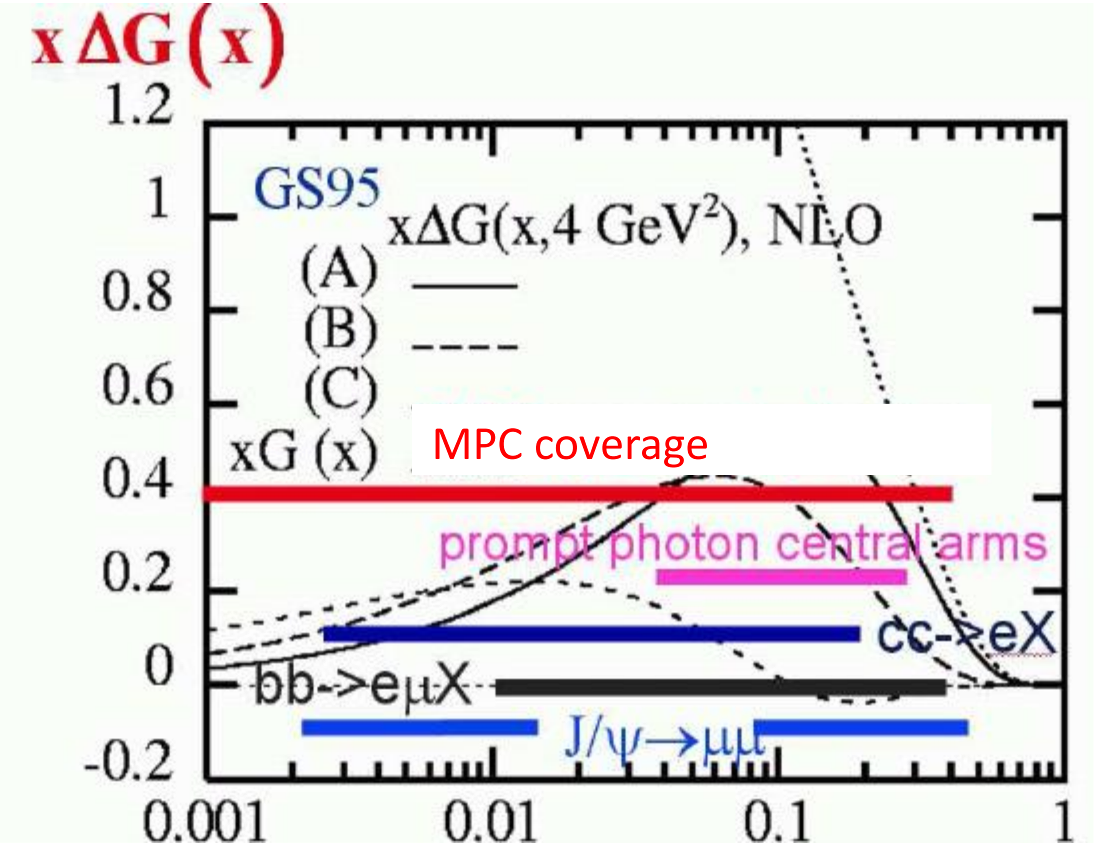
PHENIX Acceptance

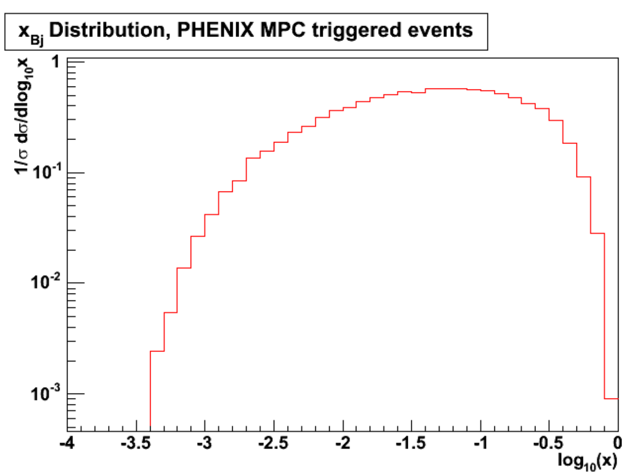


- History – PHENIX is a small acceptance, high rate, rare probes (photons, J/Psi, etc.) detector
- Future – Add acceptance plus add some new capabilities (hadron blind, displaced vertex)
- MPC, by virtue of it's location at forward rapidities, adds access to new areas, such as lower x (gluon saturated region?), higher x (valence region), even though it is a physically small detector.

MPC Reach for ΔG at low x

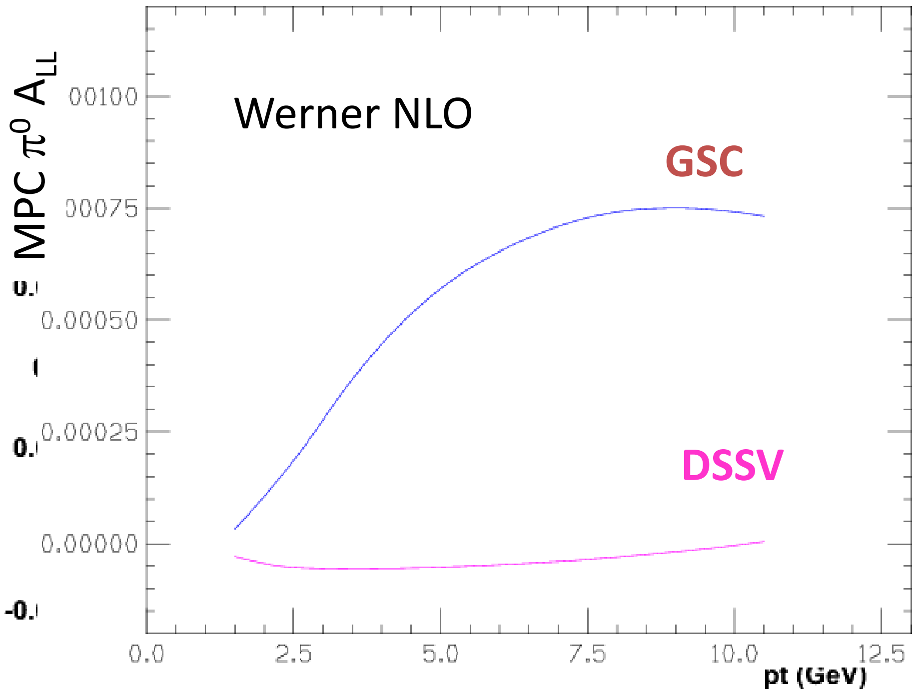
- Reminder:
  - Measurements at moderate x at SLAC on the quark structure functions were consistent with the QPM
  - Low-x measurements from CERN showed that this was not the case, i.e. it lead to the "spin crisis"
  - Recent (2005) results at even lower x from COMPASS moved ΔΣ from 0.25 to 0.3

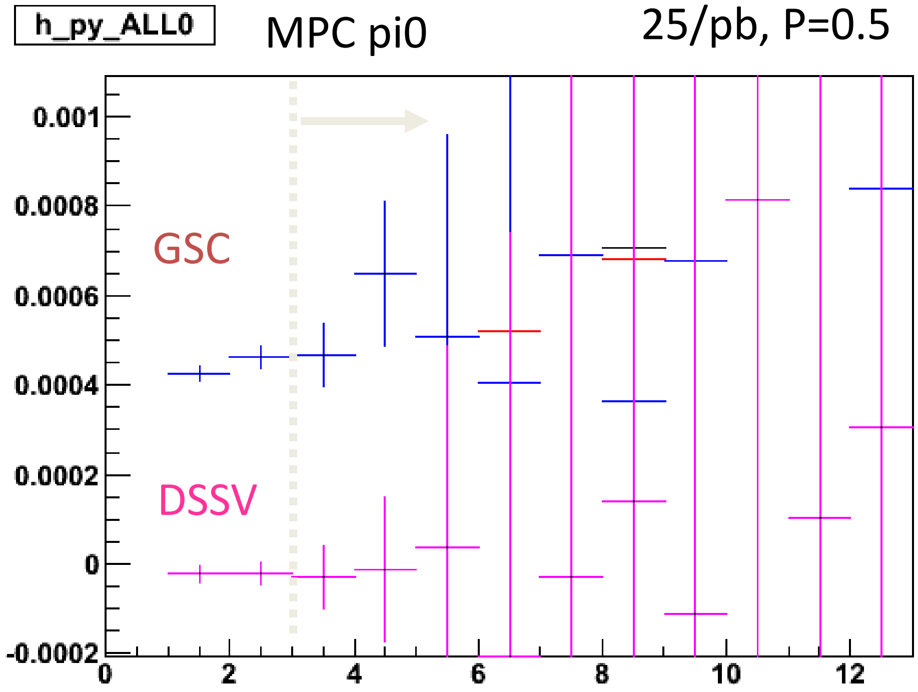




x

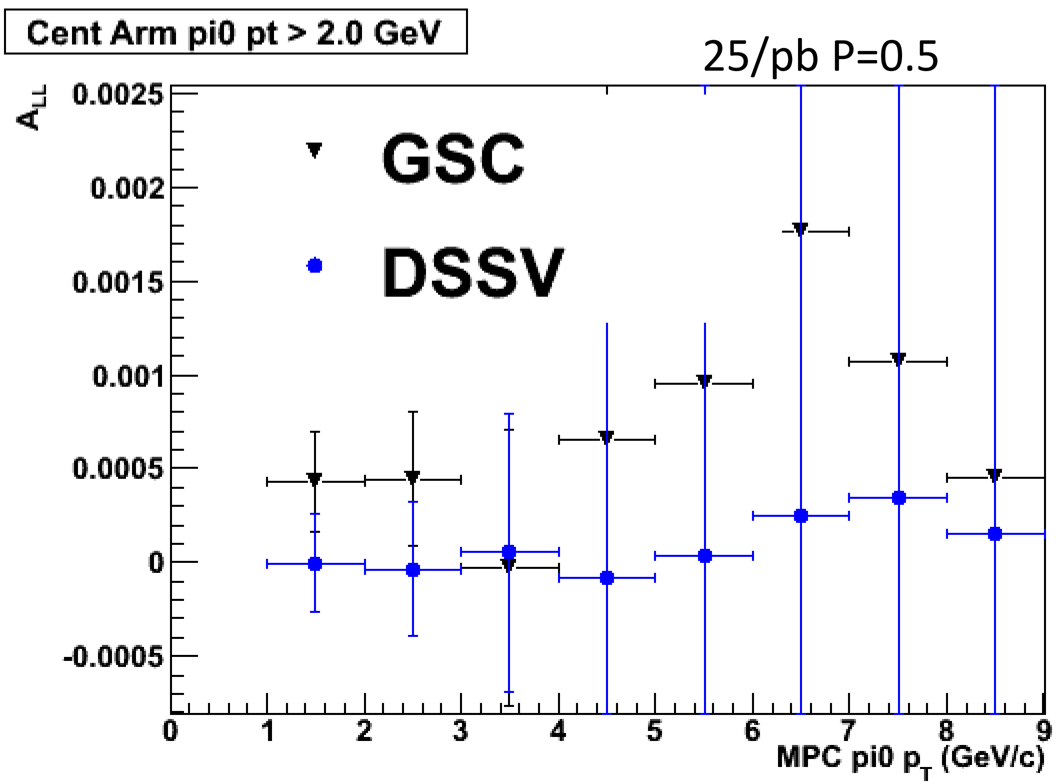
MPC Inclusive A_{LL} (circa 2009)





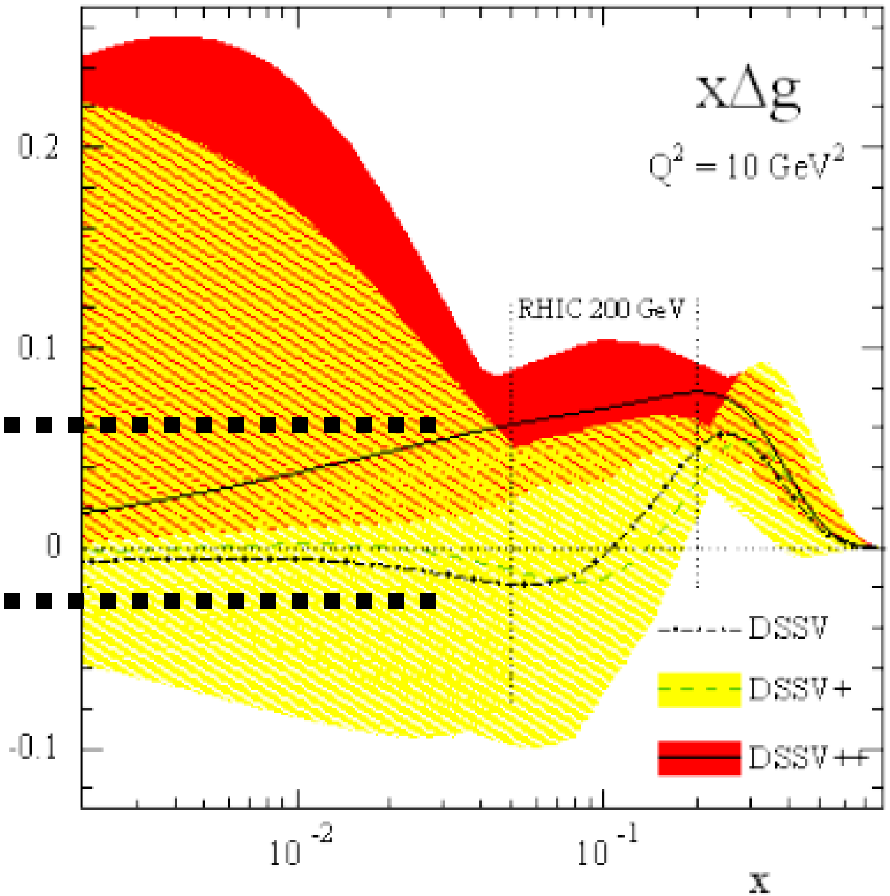
- Sizable asymmetries in inclusive sample, we should be able to determine if there is a dG ~ GSC from the next run! REALLY CONSTRAINS dG at low x.
- Pi0 and Gamma have similar A_LL??
- We should use clusters (which are mostly pi0's),and forget the clustering – much better efficiency
    - Better to be at ~3 GeV, where only a small percentage are gammas
    - Need to evaluate backgrounds (charged hadrons, other meson decays, etc)

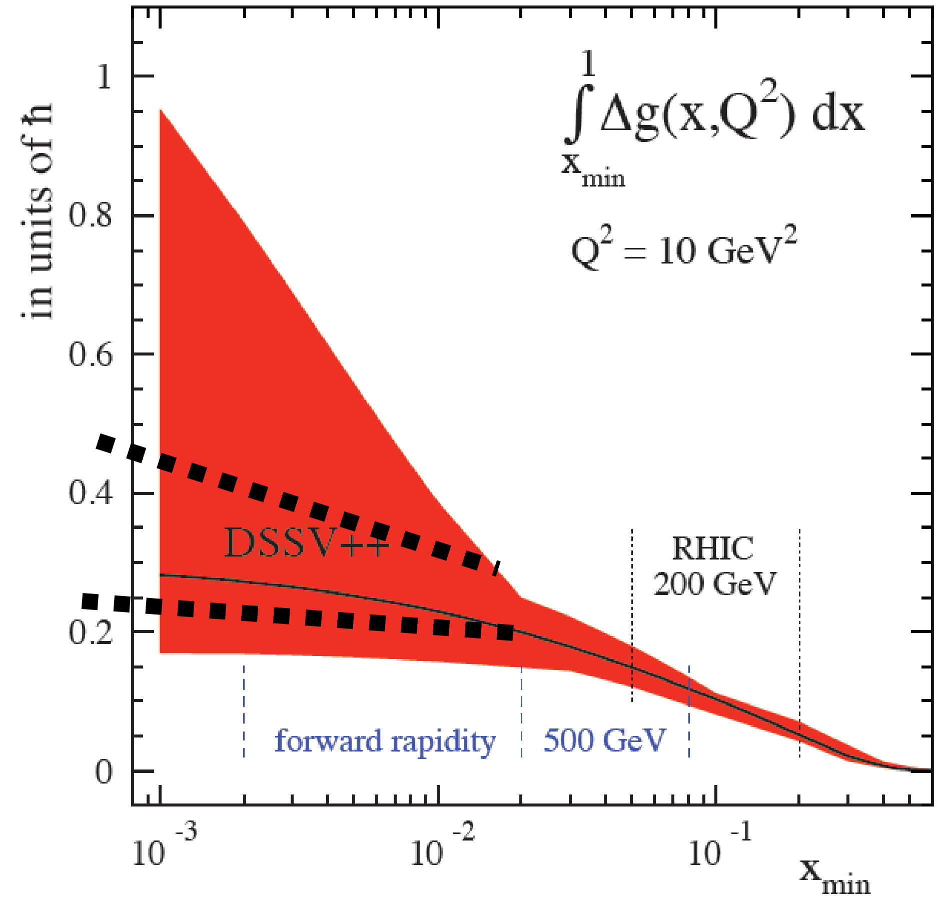
MPC-Central Arm di-pizero A_{LL}



- GSC asymmetry about $5\text{x}10^{-4}$
- Not too much sensitivity in this run…
    - But, we want a data-set to study this for future runs.
    - Eventually, at 100/pb we can get half the error bars above.
- Dilution from backgrounds not evaluated yet…

Constraint on ΔG at RHIC

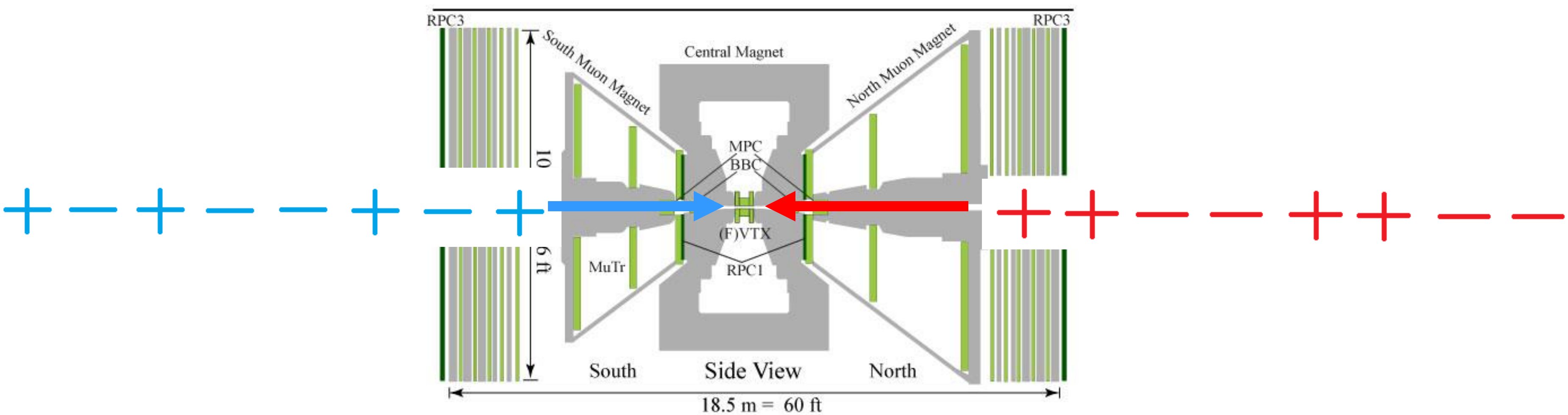




- Very roughly expect the uncertainties at low-x to drop by about 1/3-1/4 with addition of PHENIX MPC forward A_{LL}

Measuring A_{LL} at RHIC

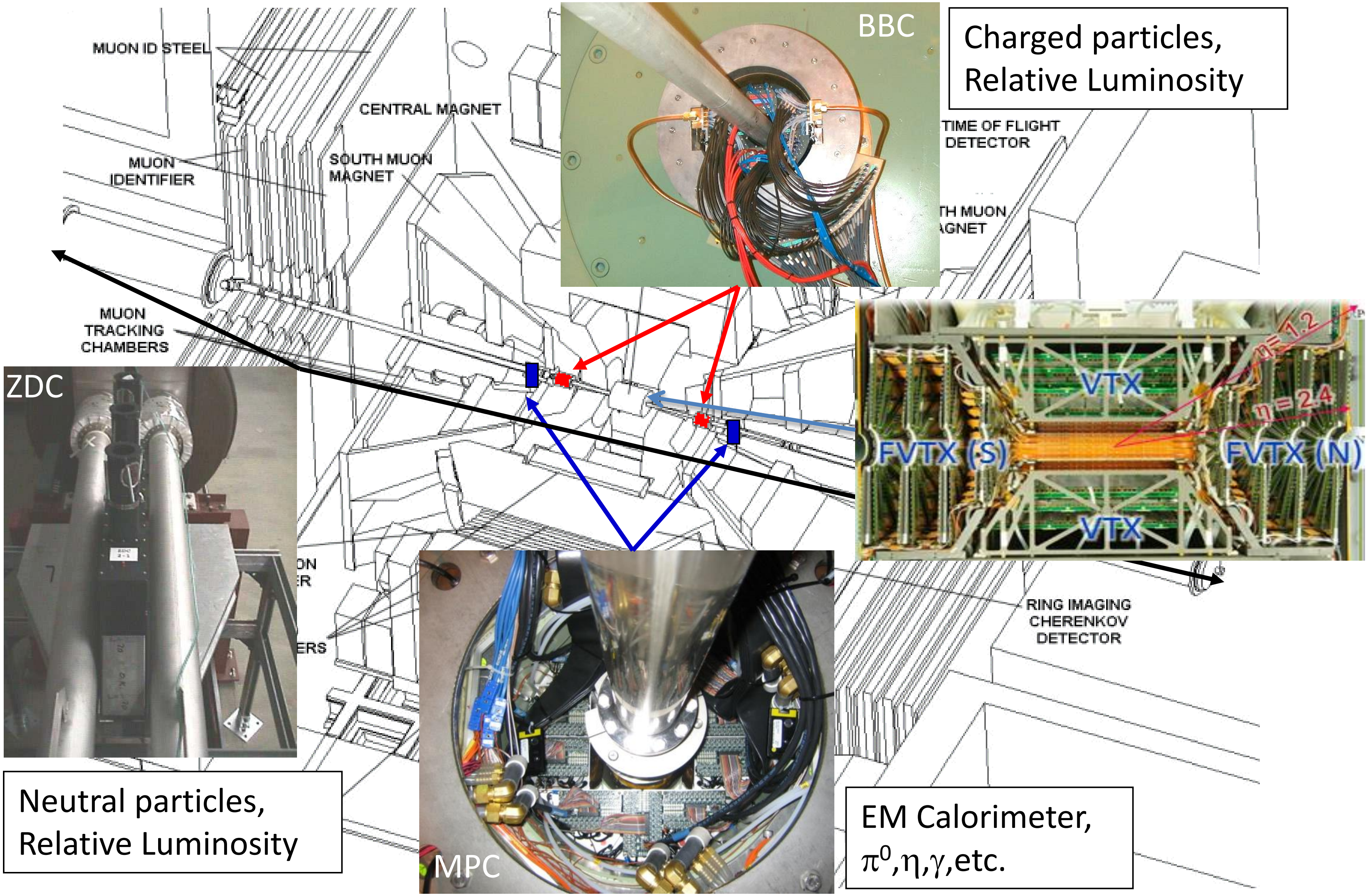
- A_{LL} is measured by determining difference in particle yields between ++ and +- crossings (with an additional factor to normalize luminosities for crossing types)
- Bunch spin patterns include ++,+-, -+, and -- crossings in each fill



$$A_{LL} = \frac{\Delta\sigma}{\sigma} = \frac{\sigma^{++} - \sigma^{+-}}{\sigma^{++} + \sigma^{+-}} = \frac{1}{< P_B P_Y >} \frac{N^{++} - RN^{+-}}{N^{++} + RN^{+-}} \qquad R = \frac{L^{++}}{L^{+-}}$$

- N is the yield of the final state measured
  - e.g. $\pi^0, \pi^{+/-}, \eta, e^{+/-}$, jets, di-hadron or di-jet states

Detectors

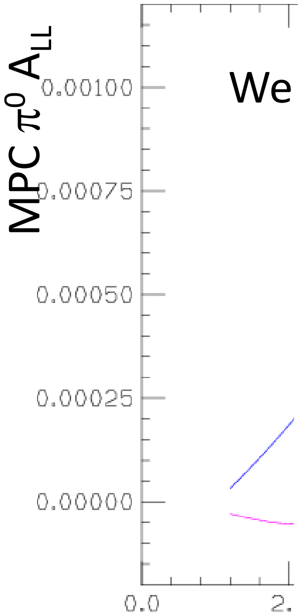


Charged particles, Relative Luminosity

Neutral particles, Relative Luminosity

EM Calorimeter, π^0,η,γ,etc.

Challenging Measurement at Low-x



We ... or History

t
x10^{-4}
x10^{-4}
10^{-4}

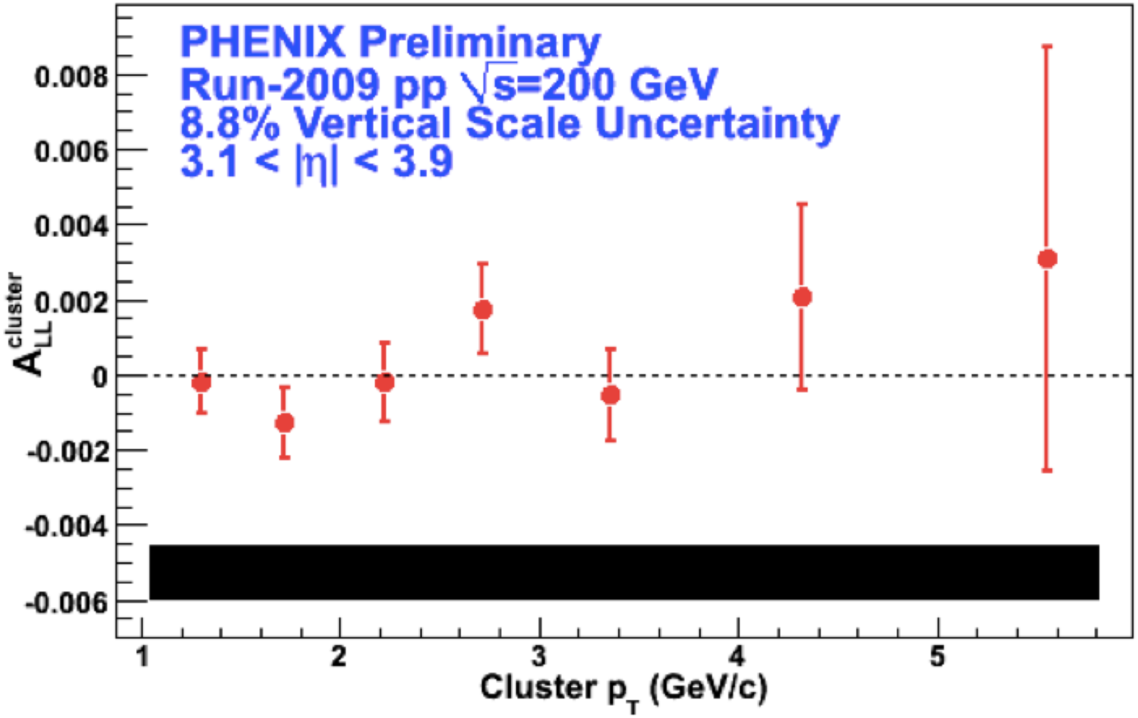


Figure 5.32: PHENIX preliminary result for $A_{LL}^{cluster}$ in the MPC.

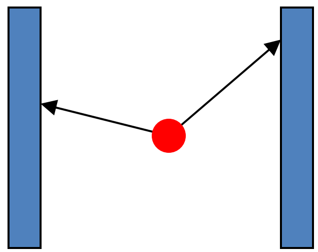
- How well v ... l as polarization
  - In 5 w ... an get ~ $9\text{x}10^8$ events.

- Until recently, Relative Luminosity has never been measured down to a level that is good enough for such a small asymmetry

Definitions

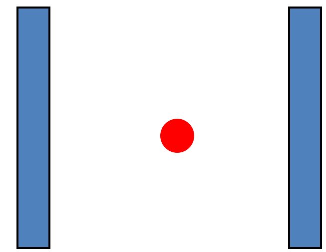
Say that we have a two arm detector, and trigger on the coincidence (eg, BBC).
We define μ as the rate of collisions per crossing, so that $\mu \in [0,\infty]$.
μ must include collisions which can produce hits in the detector. In the BBC case this will consist of the inelastic, single diffractive, and double diffractive events, but can also include elastic events.
For one collision, there are only 4 possibilities to consider:

ε_{BB} =



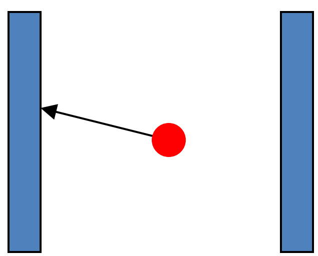
Collision hits both arms

ε_0 =



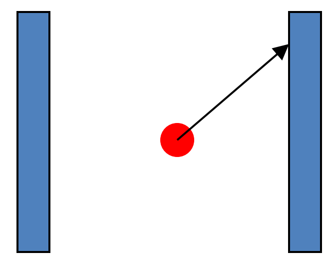
Collision hits no arms

$\varepsilon_{B,S}$ =



Collision hits south arm

$\varepsilon_{B,N}$ =



Collision hits north arm

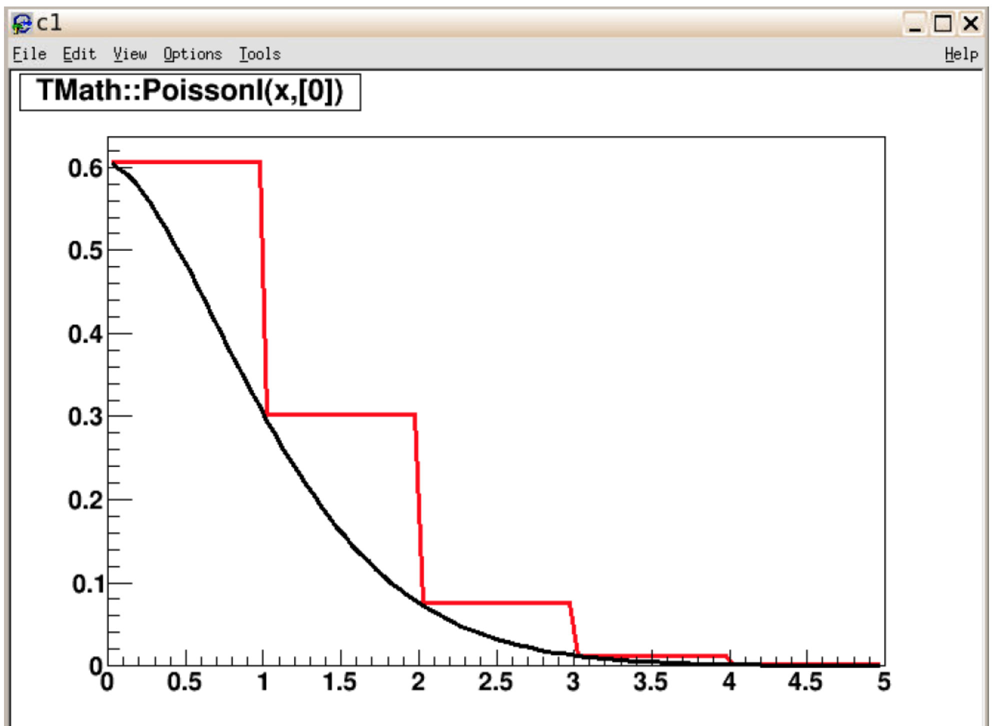
The probabilities for the four possibilities are $\varepsilon_{BB} + \varepsilon_{B,S} + \varepsilon_{B,N} + \varepsilon_0$
The total probability is $1 = \varepsilon_{BB} + \varepsilon_{B,S} + \varepsilon_{B,N} + \varepsilon_0$
In principle one can determine the probability values from clock data, except vertex dependence will be tricky as will pileup corrections.

Number of Collisions Per Crossing

Assume that the number of collisions n follows a poisson distribution, where μ is the rate of collisions:

$$P(n;\mu) = \frac{\mu^n e^{-\mu}}{n!}$$

```
TF1 *poisI = new TF1("poisI","TMath::PoissonI(x,[0])",0,5);
const double mu = 0.5;  // mean rate
poisI->SetParameter(0,mu);
```



At μ=0.5, one gets

n=0:	60%	
n=1:	30%	75%
n=2:	6%	15%
n=3:	2%	5%

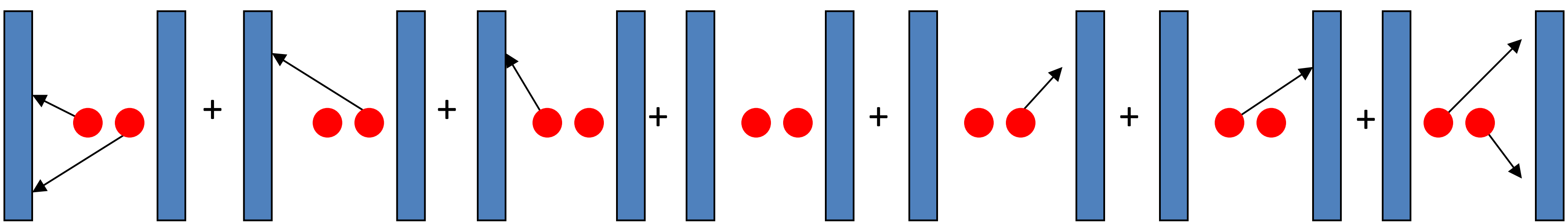
When there is a collision..

Probability of No Coincidence

The measured coincidence rate will become biased when there are more than one collision in a crossing. One will undercount when there more than one collision which will hit both arms, and it will overcount when there are multiple single collisions which hit opposite arms.
The possible combinations follow a multinomial distribution:

$$P(m_1, m_2, m_3, m_4) = \frac{n!}{m_1! m_2! m_3! m_4!} \varepsilon_{BB}^{m_1} \varepsilon_{B,N}^{m_2} \varepsilon_{B,S}^{m_3} \varepsilon_0^{m_4} \qquad m_1 + m_2 + m_3 + m_4 = n$$

One can work out all the possible combinations which will fire a coincidence. But it is simpler to calculate the probability for not firing a coincidence, by taking all combinations where the collisions produce either no hits or where the hits are all on one side, eg, for n=2 one gets



Summing up all possibilities for all n, one gets for the prob of no coincidence

$$P(0;\mu) = \sum_{n=0}^{\infty} \frac{e^{-\mu}\mu^n}{n!} \left(\sum_{m=0}^{n} \left({}_nC_m \varepsilon_{B,N}^{m} \varepsilon_0^{n-m} + {}_nC_m \varepsilon_{B,S}^{m} \varepsilon_0^{n-m} \right) - \varepsilon_0^{n} \right)$$

n is the number of collisions in a crossing, and we assume the number of collisions in a crossing is Poisson distributed.

Relation to Measured BBC Rate

$P(0;\mu)$ simplifies to

$$P(0;\mu) = e^{-\mu(\varepsilon_{BB}+\varepsilon_{B,N})} + e^{-\mu(\varepsilon_{BB}+\varepsilon_{B,S})} - e^{-\mu(\varepsilon_{BB}+\varepsilon_{B,N}+\varepsilon_{B,S})}$$

The measured rate of coincidences/crossing is then

$$R_{BB} = 1 - P(0;\mu) = 1 - e^{-\mu(\varepsilon_{BB}+\varepsilon_{B,N})} - e^{-\mu(\varepsilon_{BB}+\varepsilon_{B,S})} + e^{-\mu(\varepsilon_{BB}+\varepsilon_{B,N}+\varepsilon_{B,S})}$$

$R_{BB} = N_{BBC}/N_{Clock} \in [0,1]$, after one removes the empty crossings.
Note that we have ignored background singles, such as beam gas or beam scrape, in this analysis.
Also, we have ignored vertex effects – the ε will be a function of z-vertex.

For small μ this reduces to

$$R_{BB} \approx 1 - e^{-\mu\varepsilon_{BB}} + \mu^2\varepsilon_{B,N}\varepsilon_{B,S} \approx \mu\varepsilon_{BB} + (k_N k_S - 0.5)(\mu\varepsilon_{BB})^2$$

Ie, there is the term for undercounting due to multiple BBC coincidence events in the same crossing, and a term for overcounting due to singles accidentally forming a coincidence, and $k_N = R_{B,N}/R_{BB}$, $k_S = R_{B,S}/R_{BB}$

Practical Application

- The previous formula, one can use if one knows k_N=BBN/BBC, k_S=BBS/BBC
- One can also write the formula in terms of almost all *measured* quantities using the formula for the measured inclusive singles rates:

$$\boxed{\begin{aligned} R_{BN} &= 1 - P_{BN}(0;\mu) = 1 - e^{-\mu(\varepsilon_{BB}+\varepsilon_{B,N})} \\ R_{BS} &= 1 - P_{BS}(0;\mu) = 1 - e^{-\mu(\varepsilon_{BB}+\varepsilon_{B,S})} \end{aligned}}$$

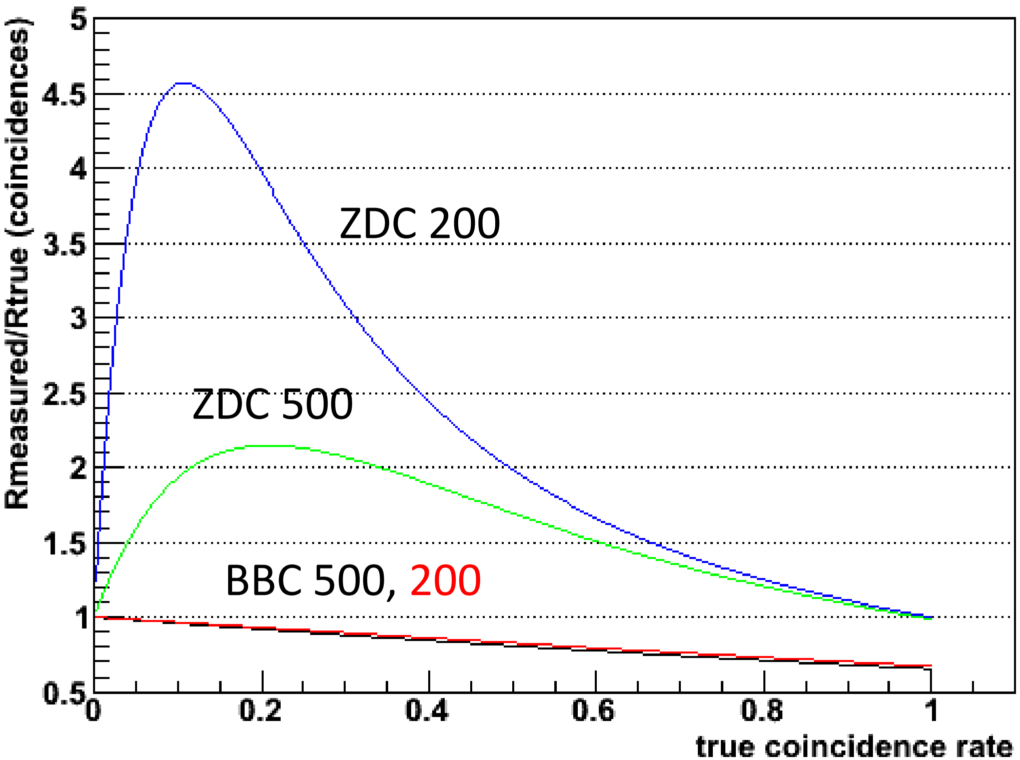
- Note that here R_{BN} (R_{BS}) include the coincidence and exclusive singles rates, ie, any hit in the north (south)

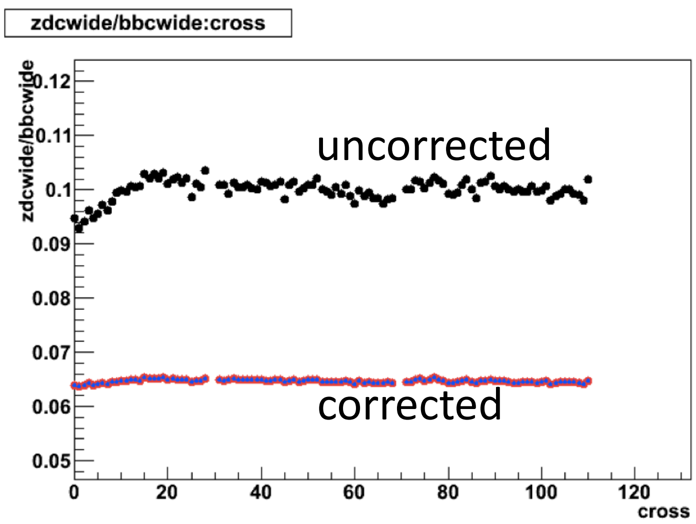
- Plugging into the formula in the previous slide, doing some algebra, one gets a relation between the measured BBC rates (singles and doubles) and the true BBC rates:

$$\boxed{\begin{aligned} R_{BB}^{True} &= \ln\left(\frac{(1-R_{BN})+(1-R_{BS})-(1-R_{BB})}{(1-R_{BN})(1-R_{BS})}\right) \\ R_{BN}^{True} &= -\ln(1-R_{BN}) - R_{BB}^{True} \end{aligned}}$$

- This is very useful for getting kN, kS

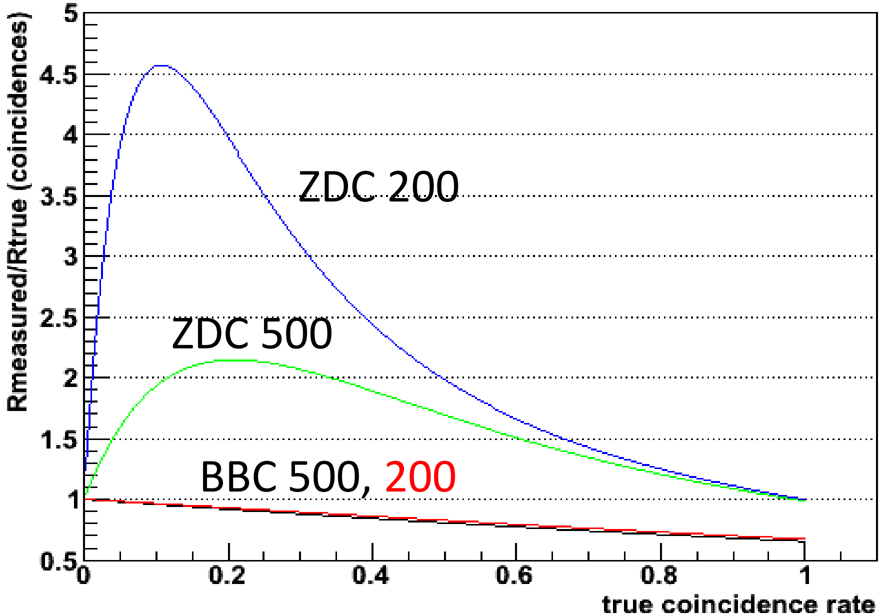
Pile Up Corrections





- There are two (equivalent) pileup corrections
- First uses the singles and doubles scalers
  - Can't be applied to vertex cut scalers
  - Noise in singles?
- Second uses the doubles scalers and the measured singles/doubles cross-section
  - Can be applied to vertex cut scaler
  - More resistant to noise?

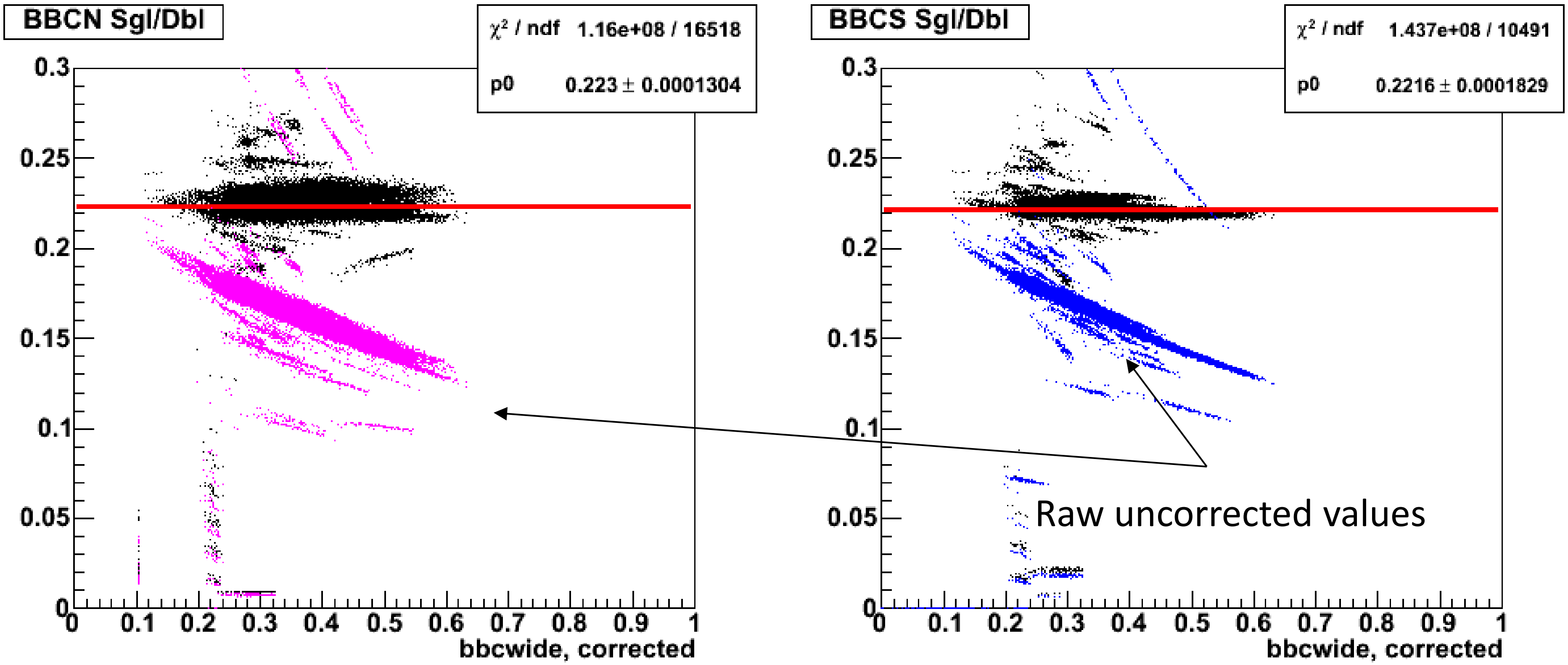
Difference 200/500



	200			500		
	Sigma (mb)	Epsilon (sig/tot)	kN,kS	Sigma (mb)	Epsilon (sig/tot)	kN,kS
BB	22.9	0.44	0.4	30	0.49	0.28
ZDC	0.2?	0.004?	10?	1.95	0.03	4
p+p Tot	51.8			60.9		

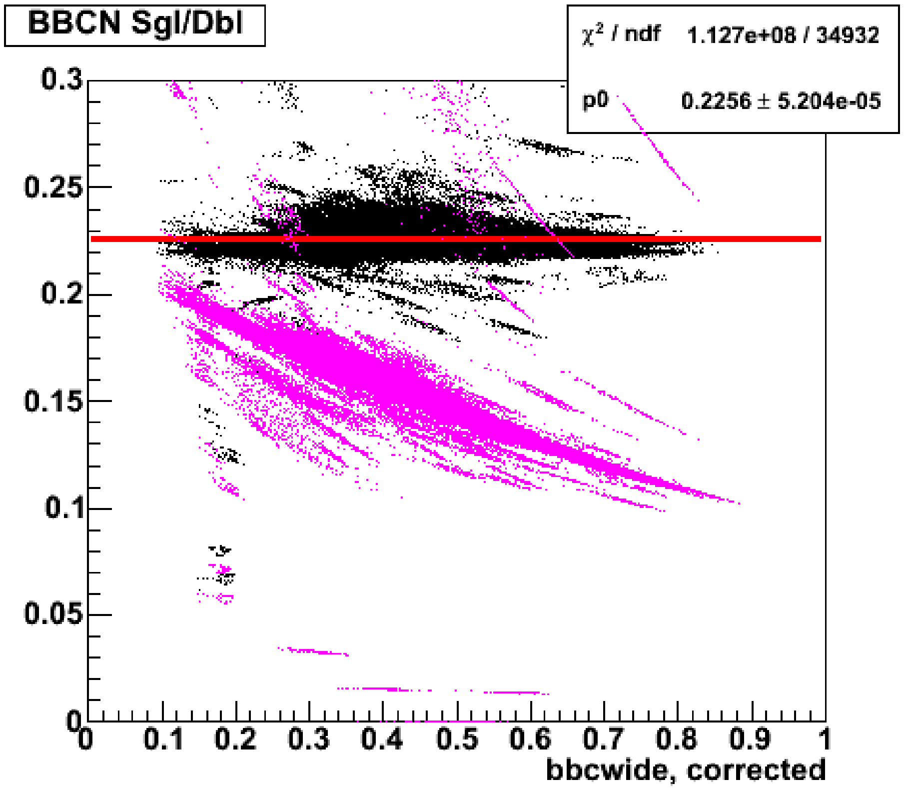
- Corrections to ZDC lumi are very large in 200 GeV
- We always wondered why in 200 (generally low rates) one needed pileup corrections…

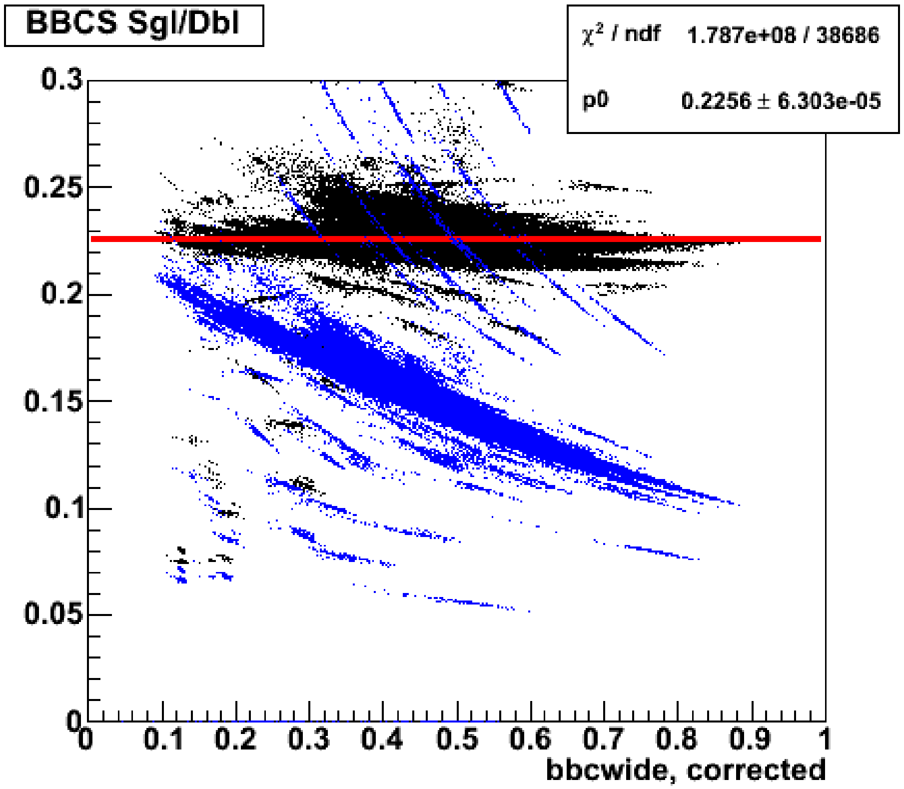
Run12 BBC Single/Double



- After proper pileup corrections, it is rate independent

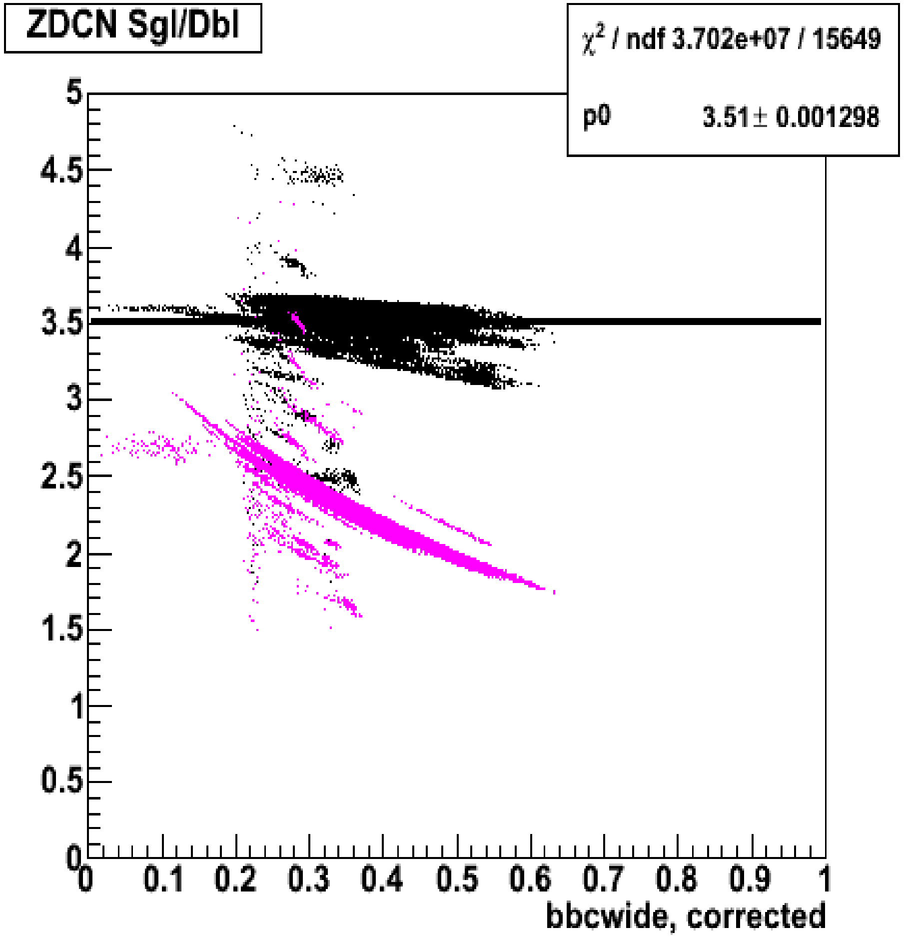
Run13 BBC Single/Double

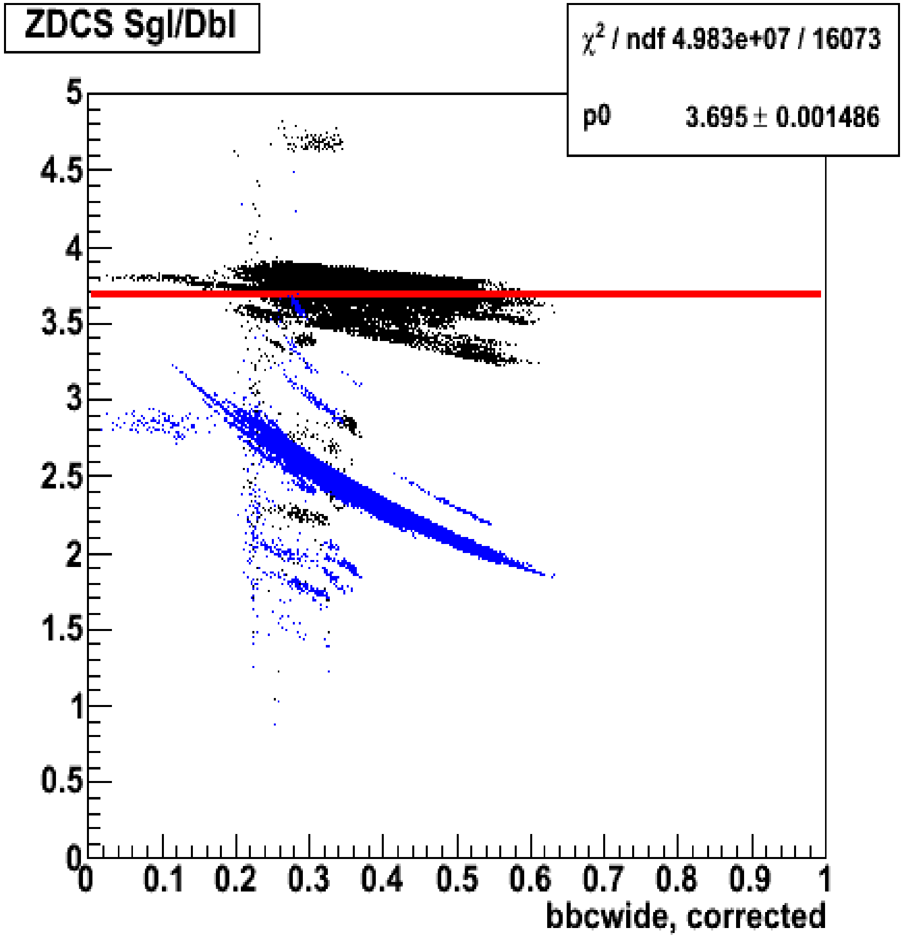




- Similar to run12, except more outliers
- In run12, both north and south BBC sgl/dbl ~ 0.23
- As a reminder, this is the exclusive sgl (eg, only south is hit, not north and south)

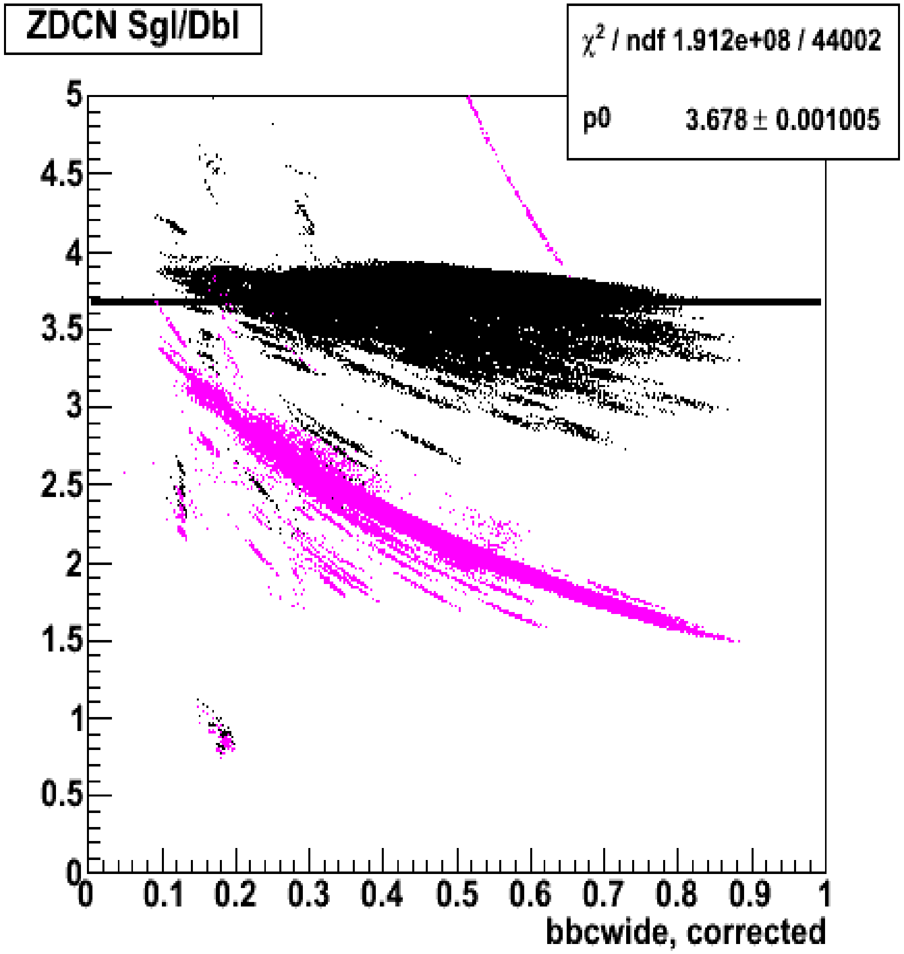
Run12 ZDC Single/Double

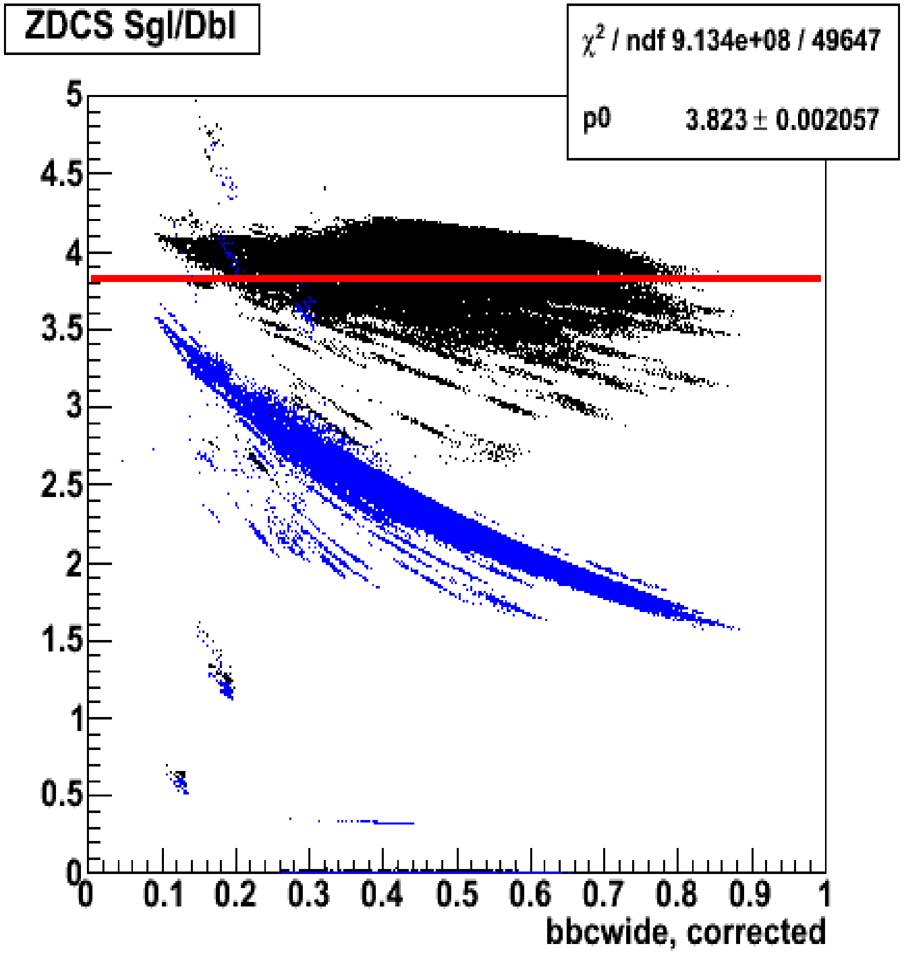




- Not sure why north and south are different
- Flattens dependence, but somehow noisy

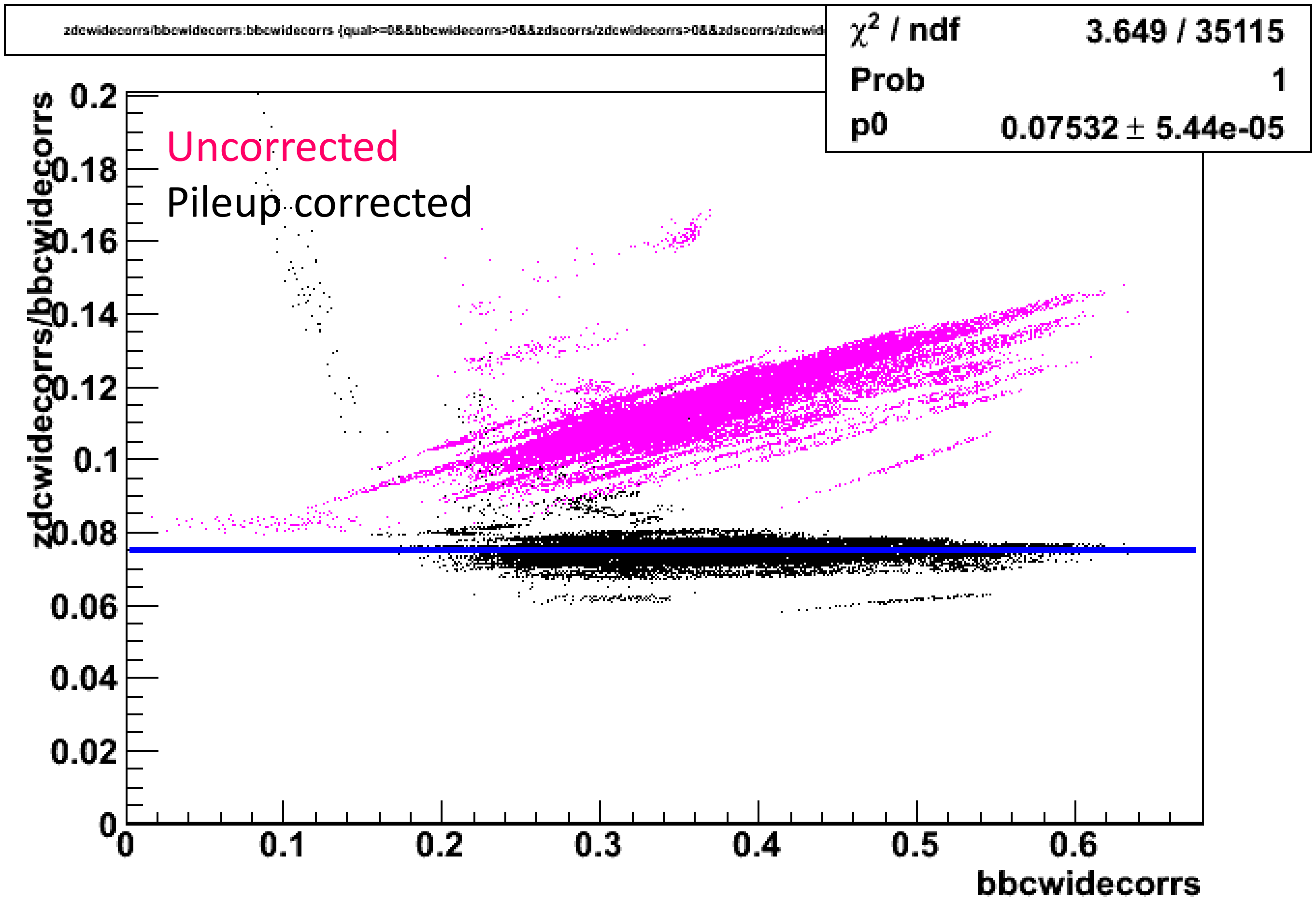
Run13 ZDC Single/Double





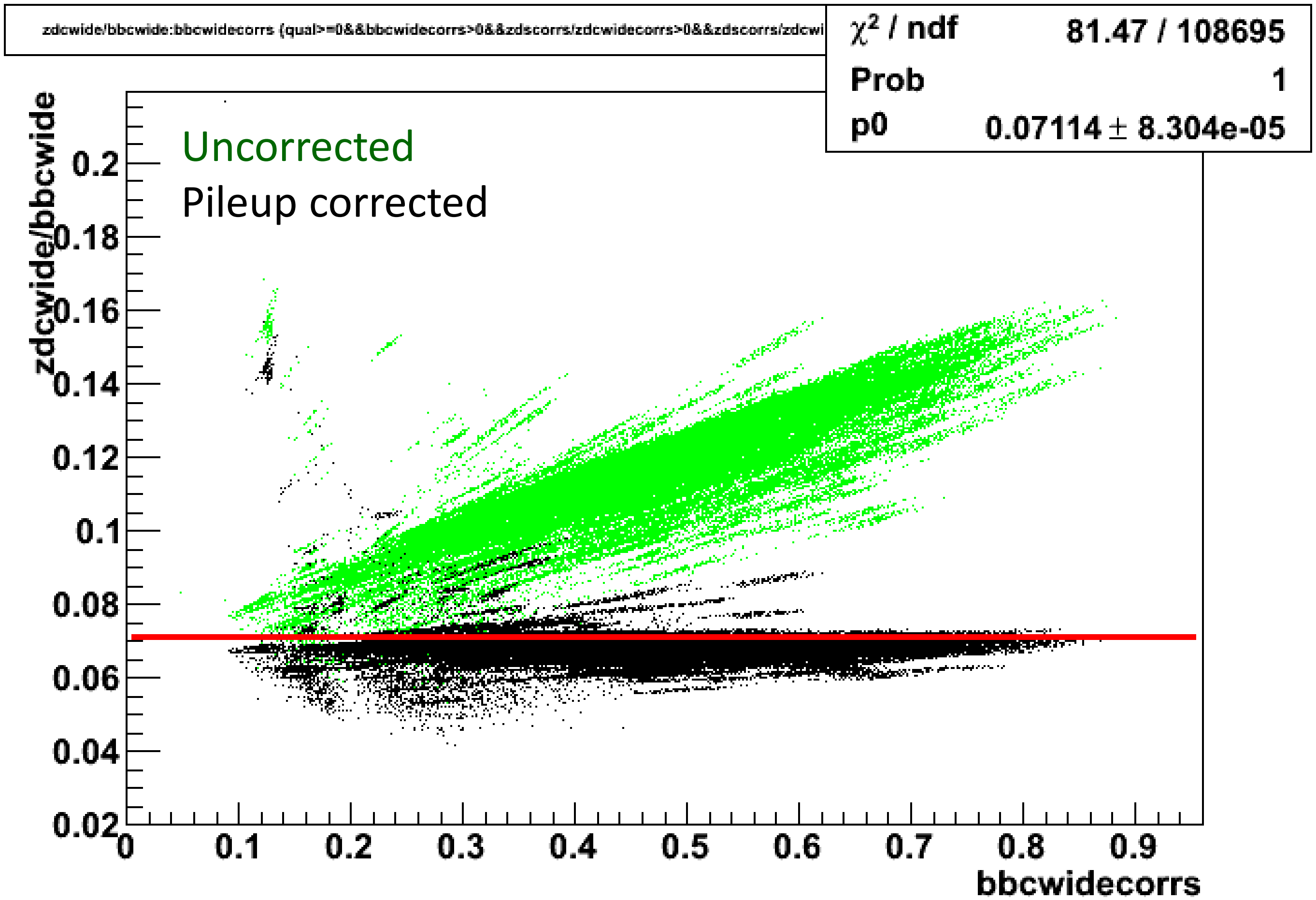
- Still different in run13
- Pileup corrections seem to flatten out ZDC sgl/dbl, but why the large spread?
- Getting kN, kS ~3.5- 3.8

Run12 ZDCwide/BBCwide



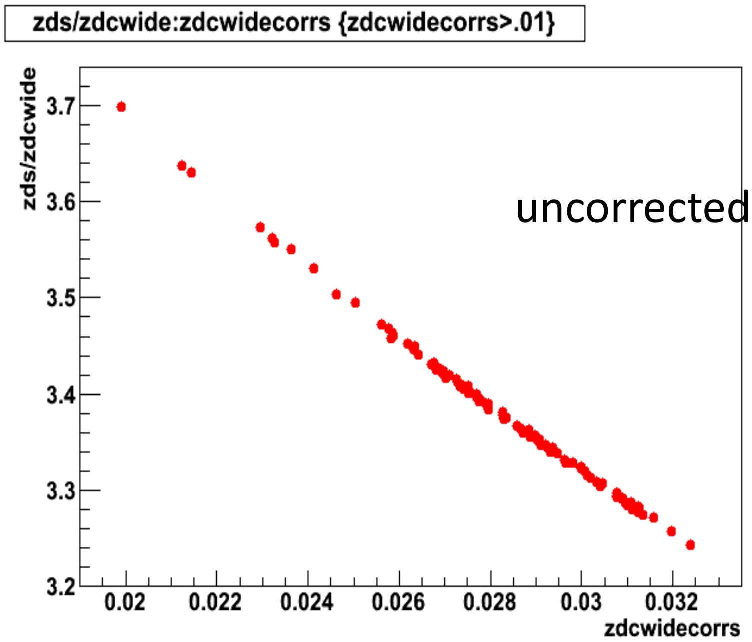
- ZDC/BBC goes flat.

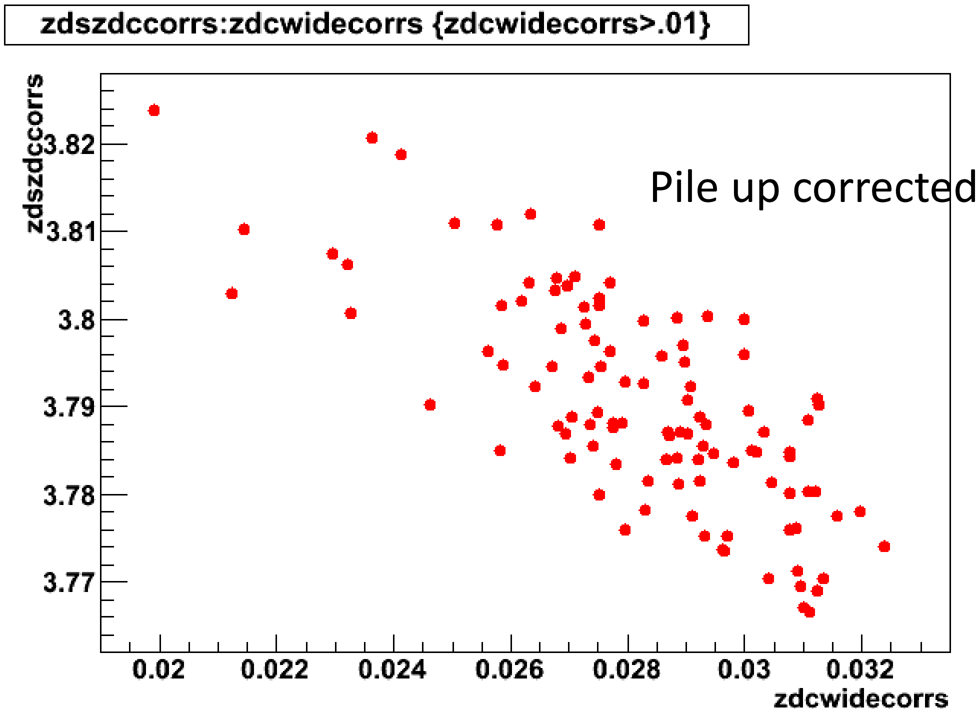
Run13 ZDCwide/BBCwide



- In run12 ZDC/BBC ~ 0.075, in run13 ZDC/BBC ~ .071

Run12 ZDC 500 GeV BBC



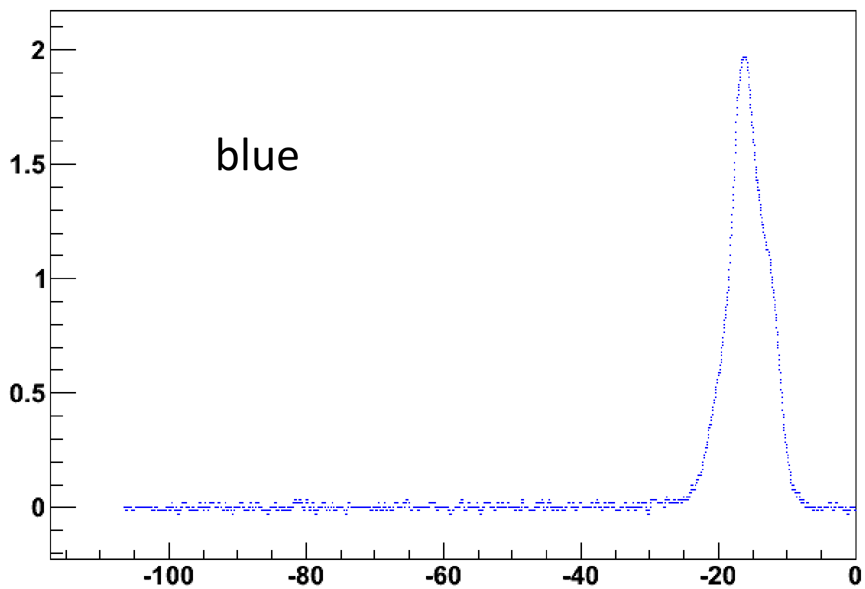


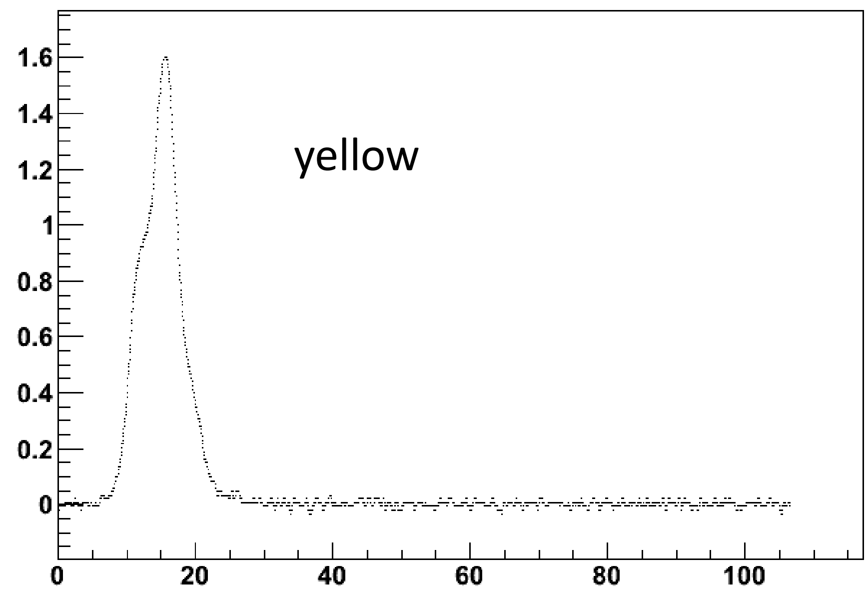
- Using STAR scalers in run12, doing pile up corrections
- Corrections bring uncorrected variation of 10% to 1%, an order of magnitude improvement.
- Expect fully corrected (from rate issues, noise, etc) to be flat.
  - originally used singles/doubles = constant as a check of rate correction formula
  - Still, 1% is not perfect.

What about vertex cut?

- The analytic corrections just do counting.
  - Cannot correct for effects of vertex cut!
- Scott's Quick Simulation of Triggers. Includes Effects from
  - Vertex Resolution (BBC=5cm, ZDC=30cm)
  - Vertex Algorithm (BBC = mean time, ZDC = earliest time)
  - Bunch width (4 ns)
  - Hourglass Effect
  - Beam Rate (0-1, ie, up to ~5 MHz BBC)
  - Singles/Double cross-sections (BBC = 0.28, ZDC = 3.52)
- Checked what happens as we put in above, so that we could try to understand what the effect is of the vertex cut after making pileup cuts.

Wall Current Monitor Info

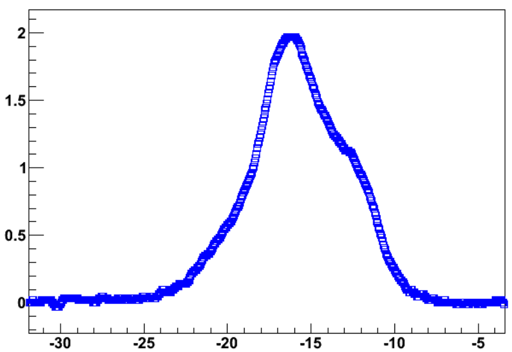


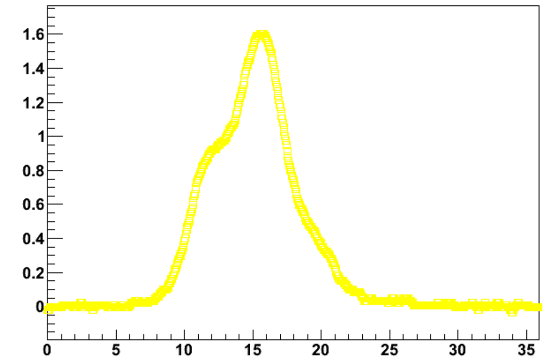


- We now have all the WCM pulses from every relevant run.
- WCM samples every 5 minutes during run.
- Could be quite powerful information…

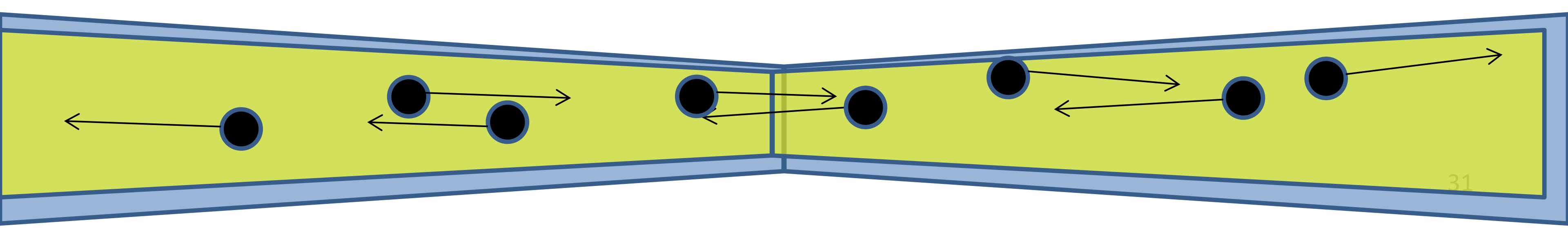
Determine event weightings

- We simulate events with a constant (t0,zvtx) distribution
- Physics events occur with a slightly different (t0,zvtx) distribution bunch to bunch
- So to weight a simulated event properly, we rely on the wall current monitor data convolution
- Here is the blue and yellow beam profile form bunch 0, run 277640, fill 10449



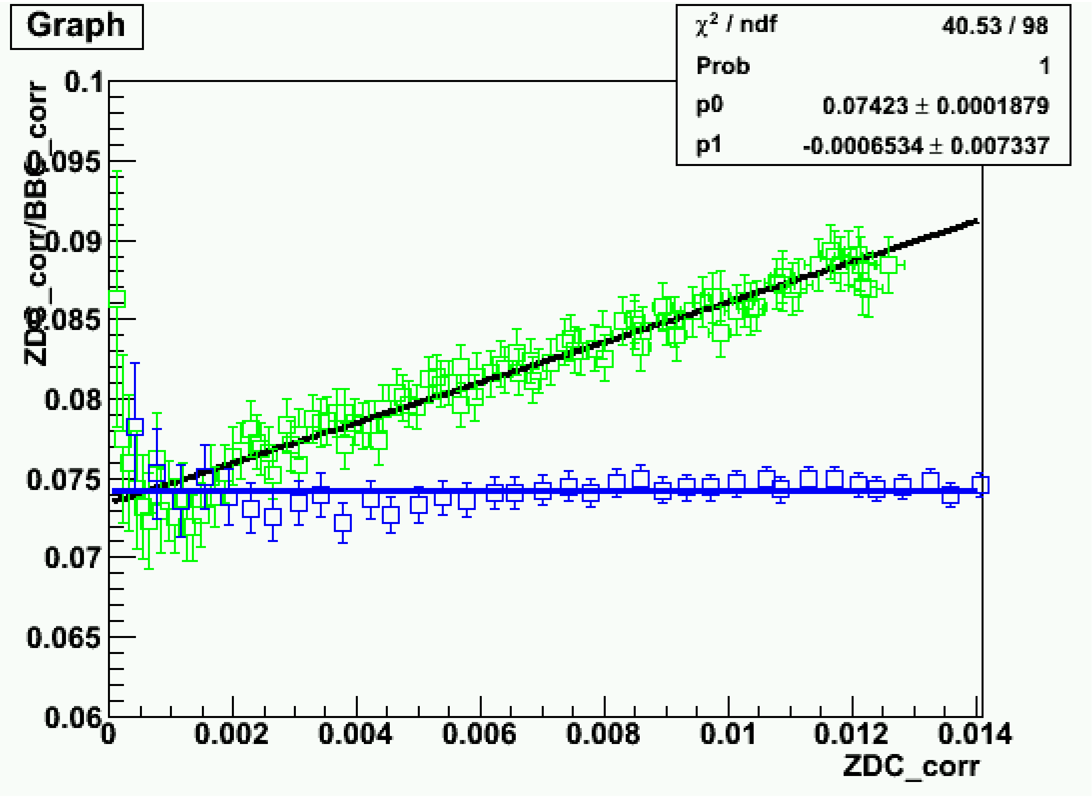


$$P(t_0, z) \propto \frac{I_{i,y} I_{j,b}}{\sqrt{1+\left(\frac{z}{\beta^*_{y,x}}\right)^2}\sqrt{1+\left(\frac{z}{\beta^*_{y,y}}\right)^2}\sqrt{1+\left(\frac{z}{\beta^*_{b,x}}\right)^2}\sqrt{1+\left(\frac{z}{\beta^*_{b,y}}\right)^2}}$$



ZDC_corr/BBC_corr vs ZDC_corr

30 cm
200 cm

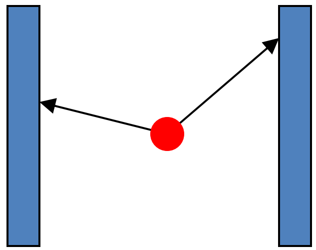


- When using corrected rates, with a 200 cm vertex cut there is no residual correlation, as expected.
- With 30 cm cut, there is a strong residual correlation.
- Rate correction formula used is below.

$$R_{BBC} = 1 - e^{-\mu\epsilon_{BB}(1+k_N)} - e^{-\mu\epsilon_{BB}(1+k_S)} + e^{-\mu\epsilon_{BB}(1+k_N+k_S)}$$

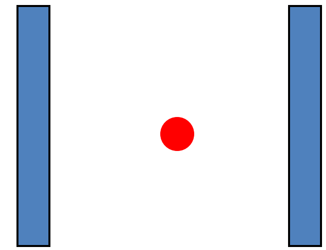
What about noise?

ε_{BB} =



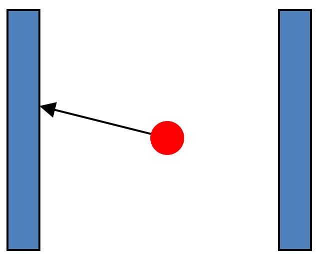
Noise hits both arms

ε_0 =



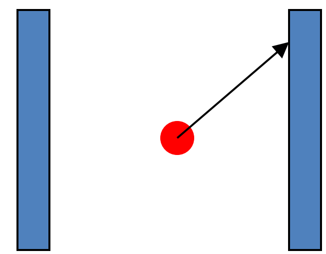
Noise hits no arms

$\varepsilon_{B,S}$ =



Noise hits south arm

$\varepsilon_{B,N}$ =



Noise hits north arm

- The total probability is still $1 = \varepsilon_{BB} + \varepsilon_{B,S} + \varepsilon_{B,N} + \varepsilon_0$
- However, it now doesn't count collisions properly!
    - One MUST have a way to separate out noise.
- We attempt to do that by determining kN, kS… and using only the coincidence triggers, which are relatively noise free.
- Another nice feature of the kN, kS formulation is that one can use it on vertex cut scalers.

Outline of Analytic Approach

To understand where the residual correction comes from.
Given in Scott Wolin's Thesis, chapter 9.

Very simple idea. Just take the 1st order approximation for the 2 collision case.

But the scaled value is not R_{obs}, the no vertex uncorrected scaler, rather $R_{obs,vtx} = fR_{obs}$. In terms of this we get:

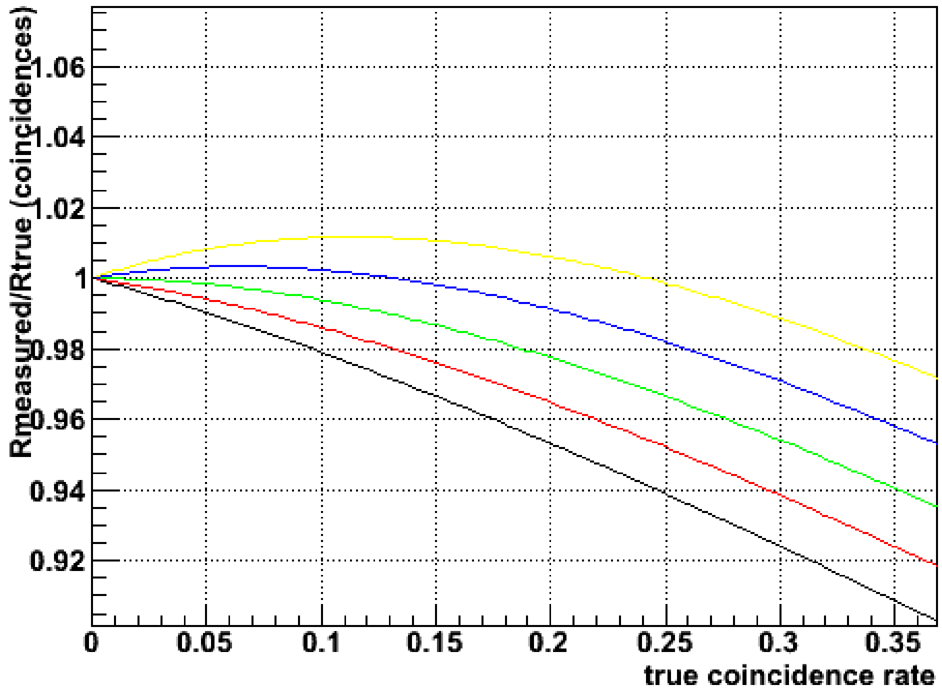
$$R_{true} = R_{true,vtx} \times \frac{1 - \frac{K}{f} R_{obs,vtx}}{f\left(1 - KR_{obs,vtx}\right)} \tag{9.10}$$

We define the residual correction factor by:

$$C_{res} \equiv \frac{1 - \frac{K}{f} R_{obs,vtx}}{\left(1 - KR_{obs,vtx}\right)} \tag{9.11}$$

End up with a simple formula for the Residual correlation factor which is within about 10% consistent with the measured residual correlation.

How good is Scott's approximation?



at the interesting conclusion, in this approximation, that over-counting and undercounting cancel when

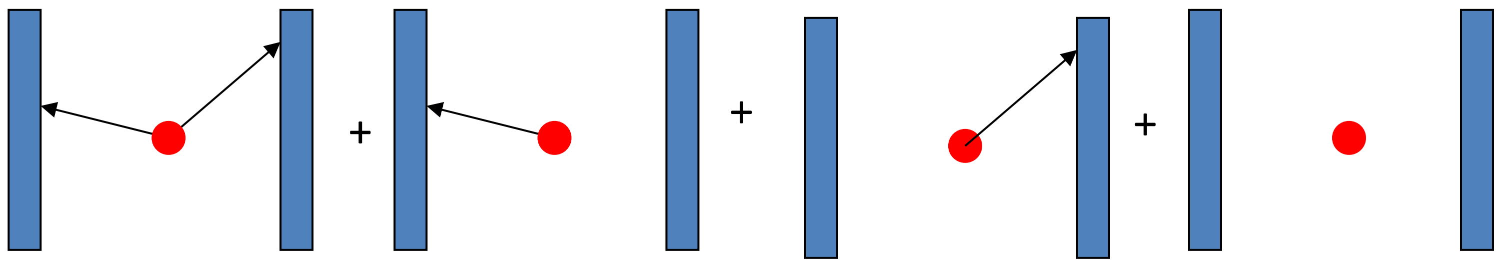
$$K \equiv k_N k_S - \frac{1}{2} = 0 \tag{9.1}$$

Green line above is the kN value when the over and under counting cancel.
Approximation good to better than 1% until rate = 0.1
Still studying region of validity…
Can do higher order corrections

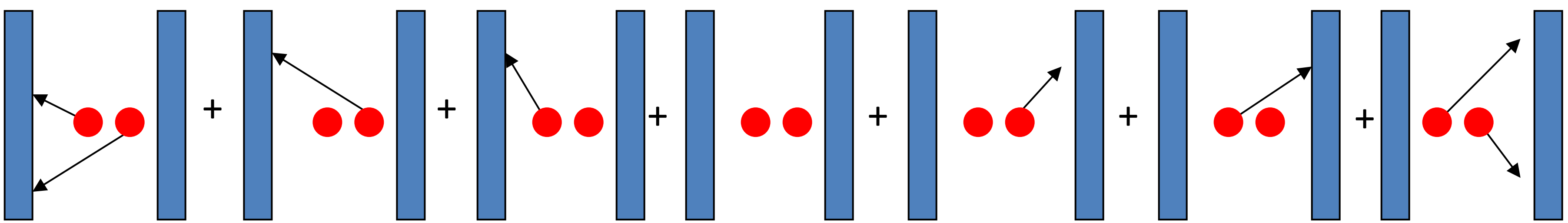
Outline of Simulation Approach

Generate the vertex distribution using the WCM
We check this generated vertex against data.

Simulate in pisa one collision/crossing



Plus two collisions/crossing (put two collisions into simulation)



Plus all three and four collision crossings. It is very unlikely to have more than 4 collisions, so one can ignore it (at least for run9, might need to revisit in)

We have the measured scaler rate… just vary the true rate in the right poisson proportion for that rate until we match the measure rate. That gets us the true rate.

To get true beam rate

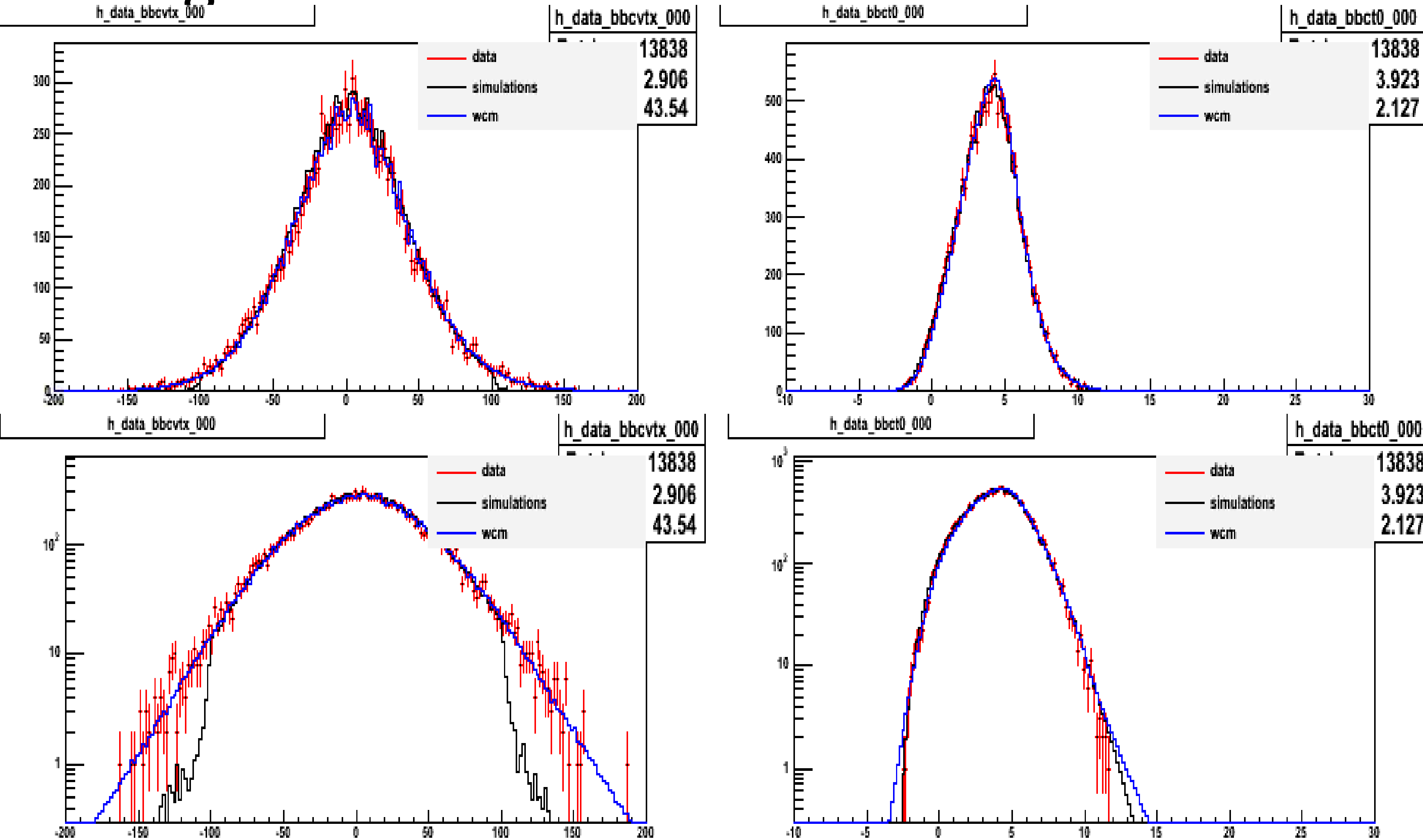
- So the basic equation that must be solved for the beam rate is:

$$\frac{N_{BBC(>0tubes)}}{N_{CLOCK}} = \sum_{icoll=1}^{4} \frac{N_{icoll,BBC(>0tubes)}}{N_{icoll}} \times \frac{N_{icoll}}{N_{CLOCK}}$$

$$\boxed{\frac{N_{BBC(>0tubes)}}{N_{CLOCK}} = f_1 \mu e^{-\mu} + \frac{1}{2} f_2 \mu^2 e^{-\mu} + \frac{1}{6} f_3 \mu^3 e^{-\mu} + \frac{1}{24} f_4 \mu^4 e^{-\mu}}$$

- NBBC/Nclock is the measured BBC 30cm rate from the gl1p
- The total beam rate enters through poisson statistics
- The f's encompass the bbc efficiency and rate corrections at the same time and so f_i represents the fraction of crossings with i pp collisions that cause the BBC 30cm trigger to fire.
- So instead of making combinatorial arguments, we need to derive the f_i. The real work of this method is to do this.

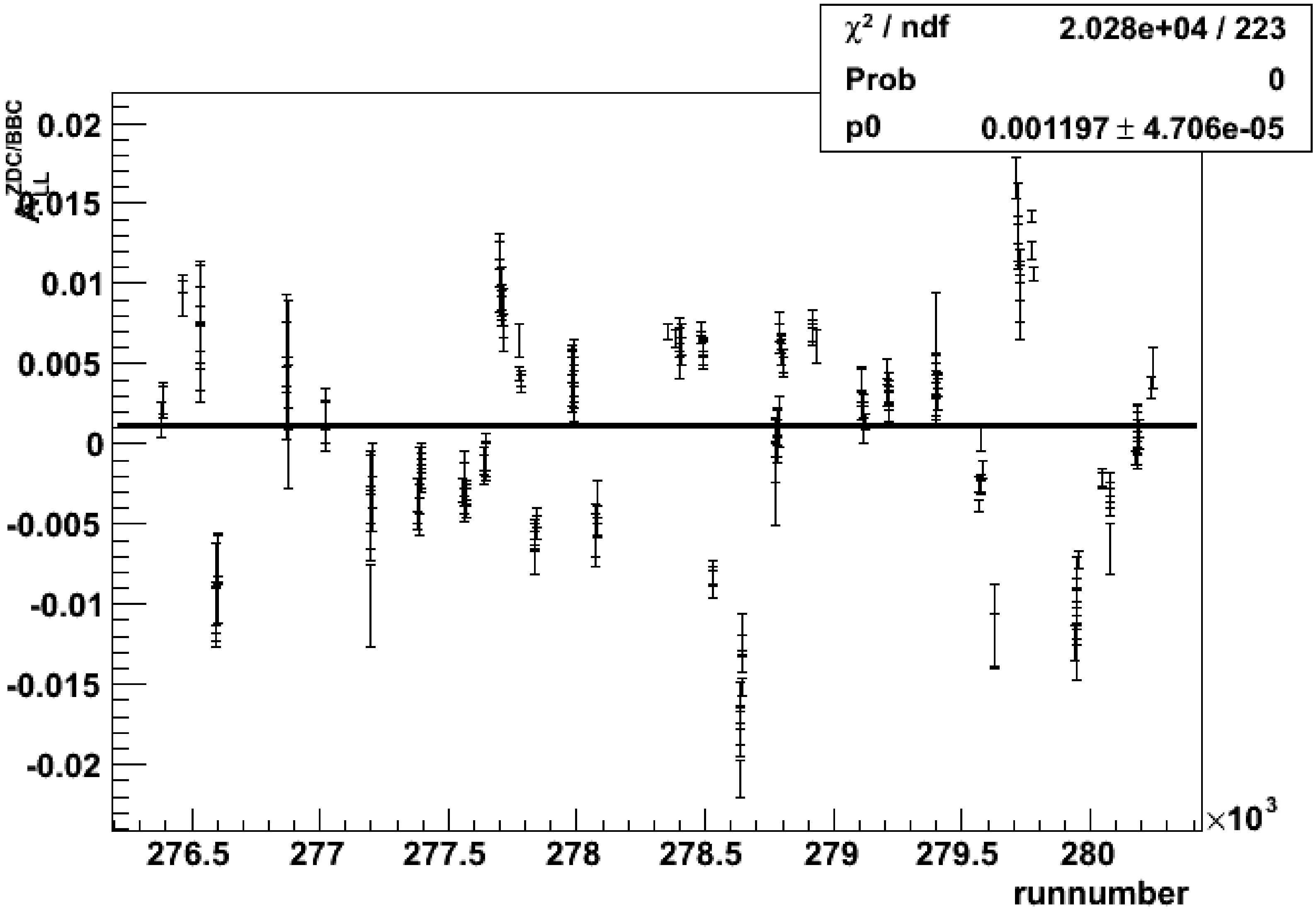
Agreement of WCM to data: zvtx and t0



- Top plots zvtx/t0 on linear scale, bottom on log scale

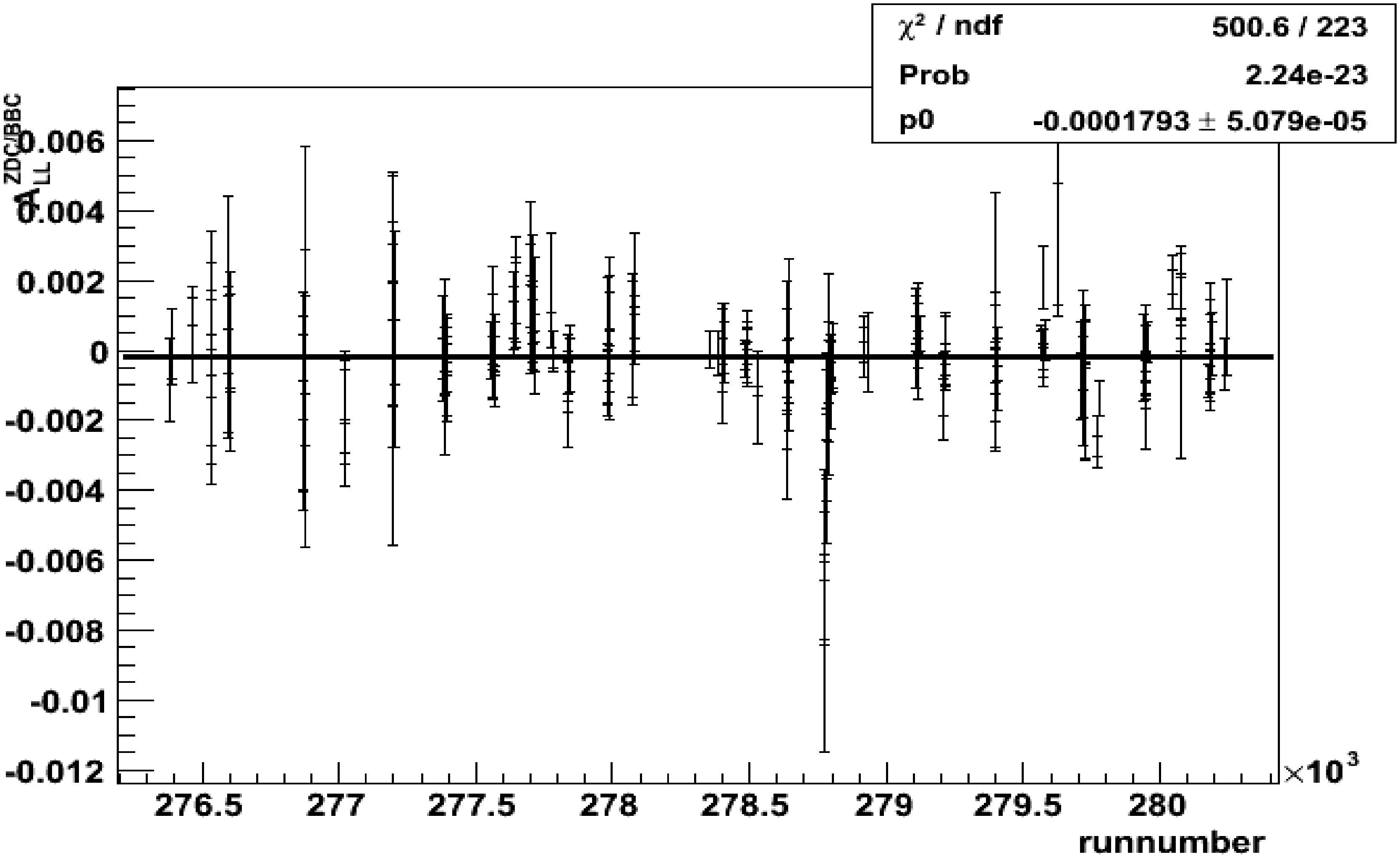
Slide from Scott

Run9pp500, No Corr



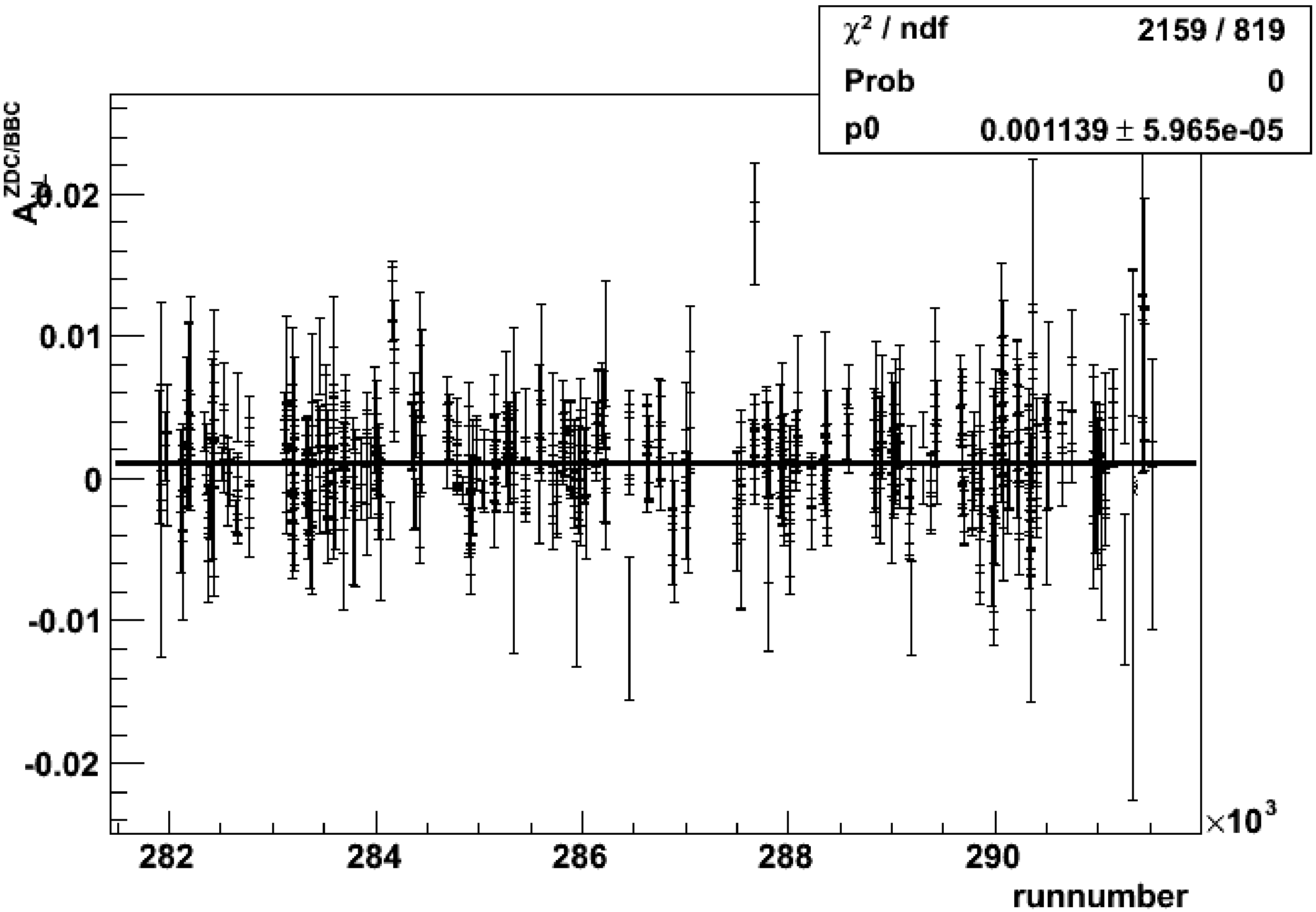
- As a sanity check, I looked at run9pp500, ie, Scott's analysis

Run9pp500, pileup+zdc residual



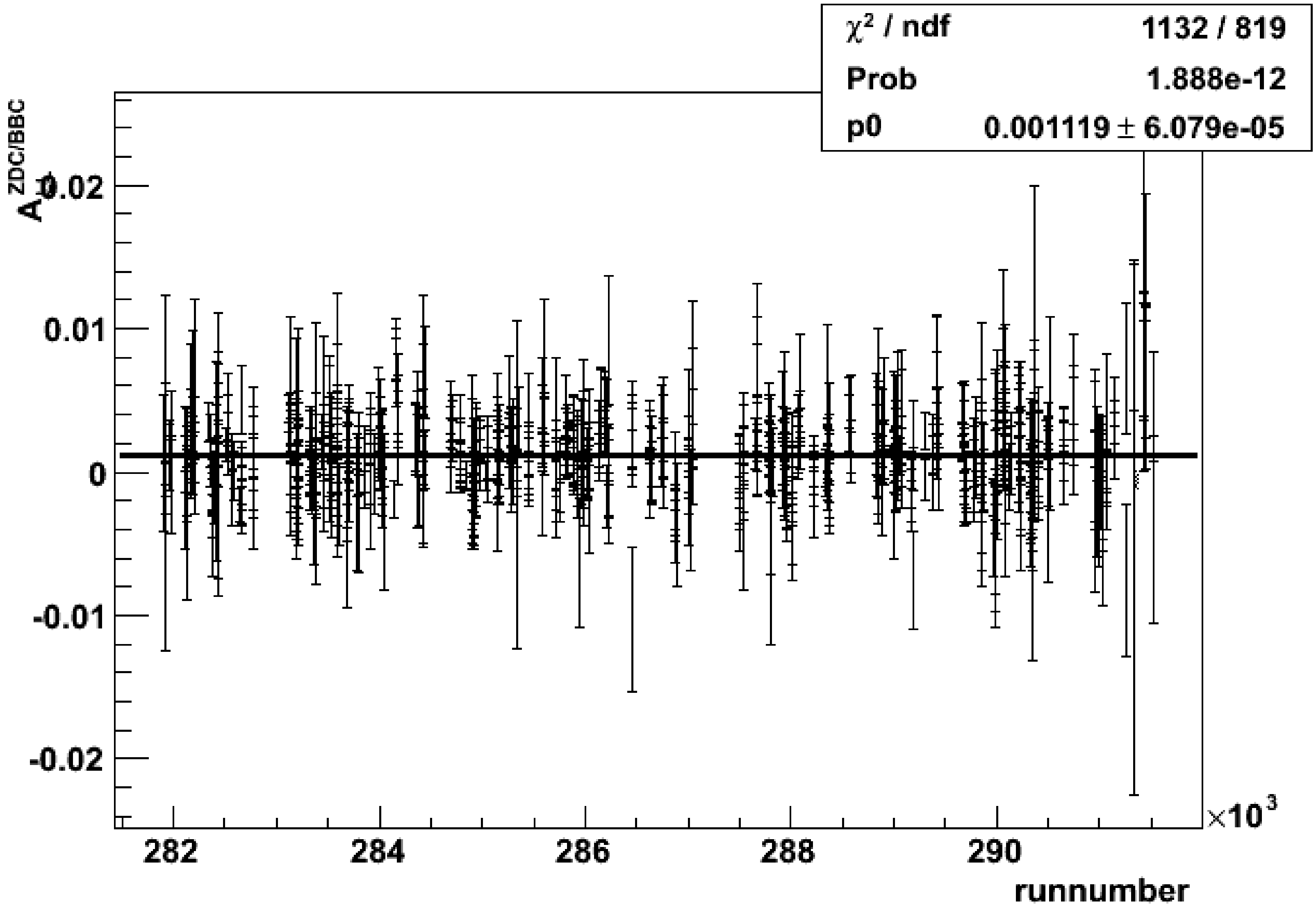
- I recover ~Scott's result, ALL(ZDC/BBC) ~ -2e-4
- Not sure why chi2 is not so great, but I think it is similar to Scott's.
- I looked into run12pp500, and that also got a low value for ALL(ZDC/BBC) (but poor chi2)

Run9pp200 GL1P Scalers, No Corr



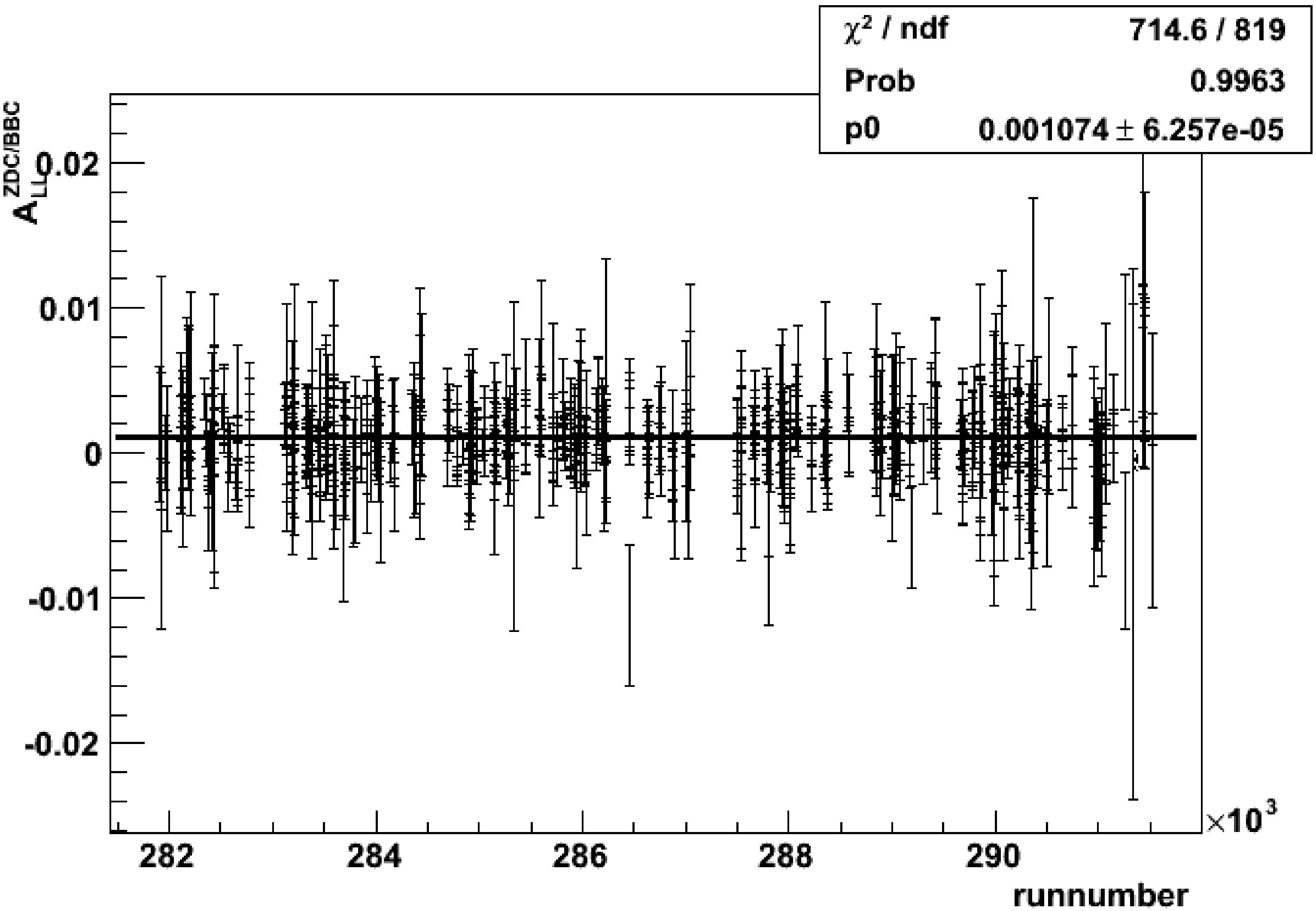
- Got full BBC sims running, but while doing this I decided to check if Scott's ZDC residual correction would just work
- Using run9pp200 GL1P scalers, no corrections, get 11.4e-4 ALL(ZDC/BBC)

Run9pp200, Pileup Corr



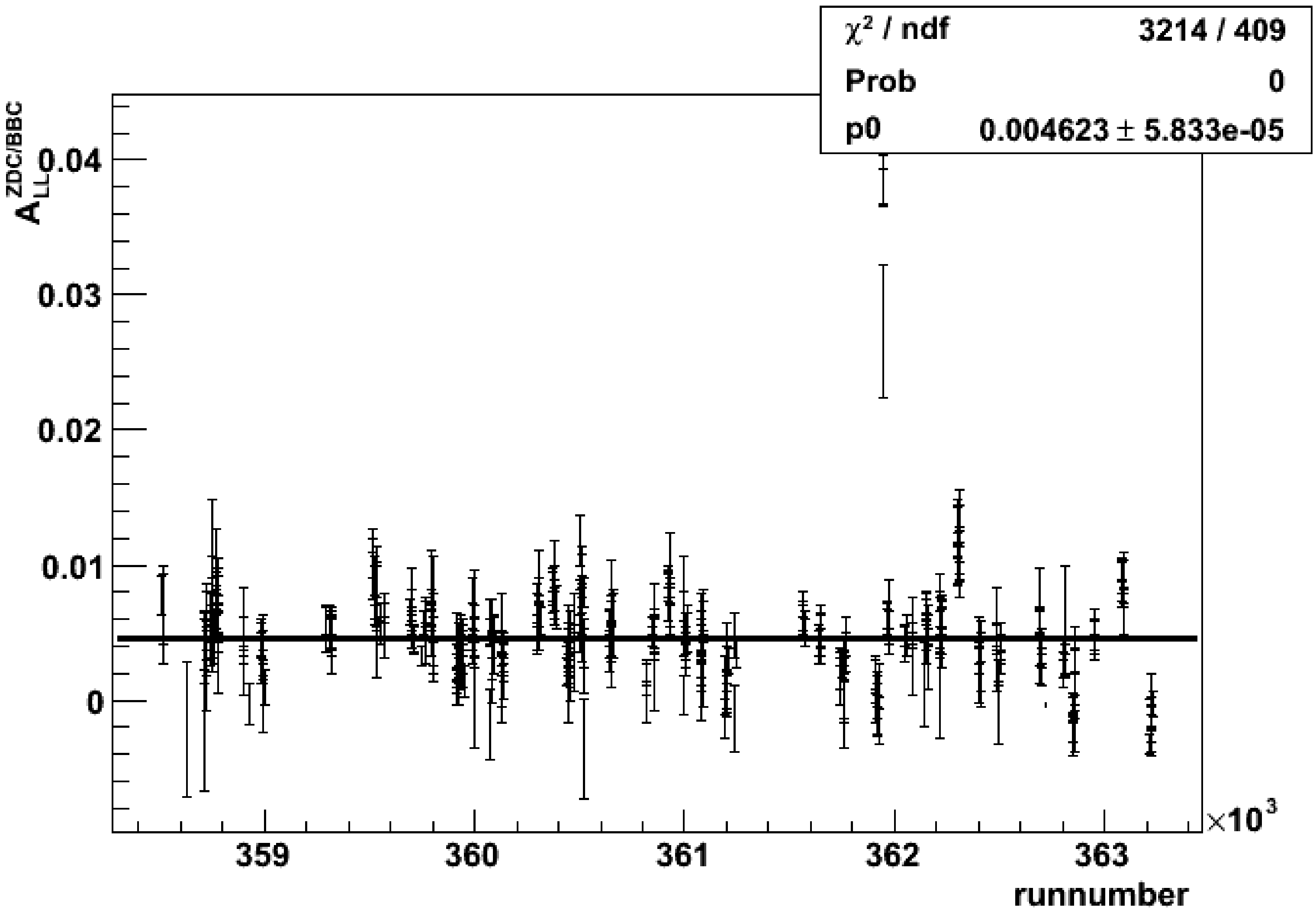
- With pileup correction, ALL(ZDC/BBC) stays the same, but chi2 improved by factor 2.

Run9pp200, Pileup+ZDC Residual



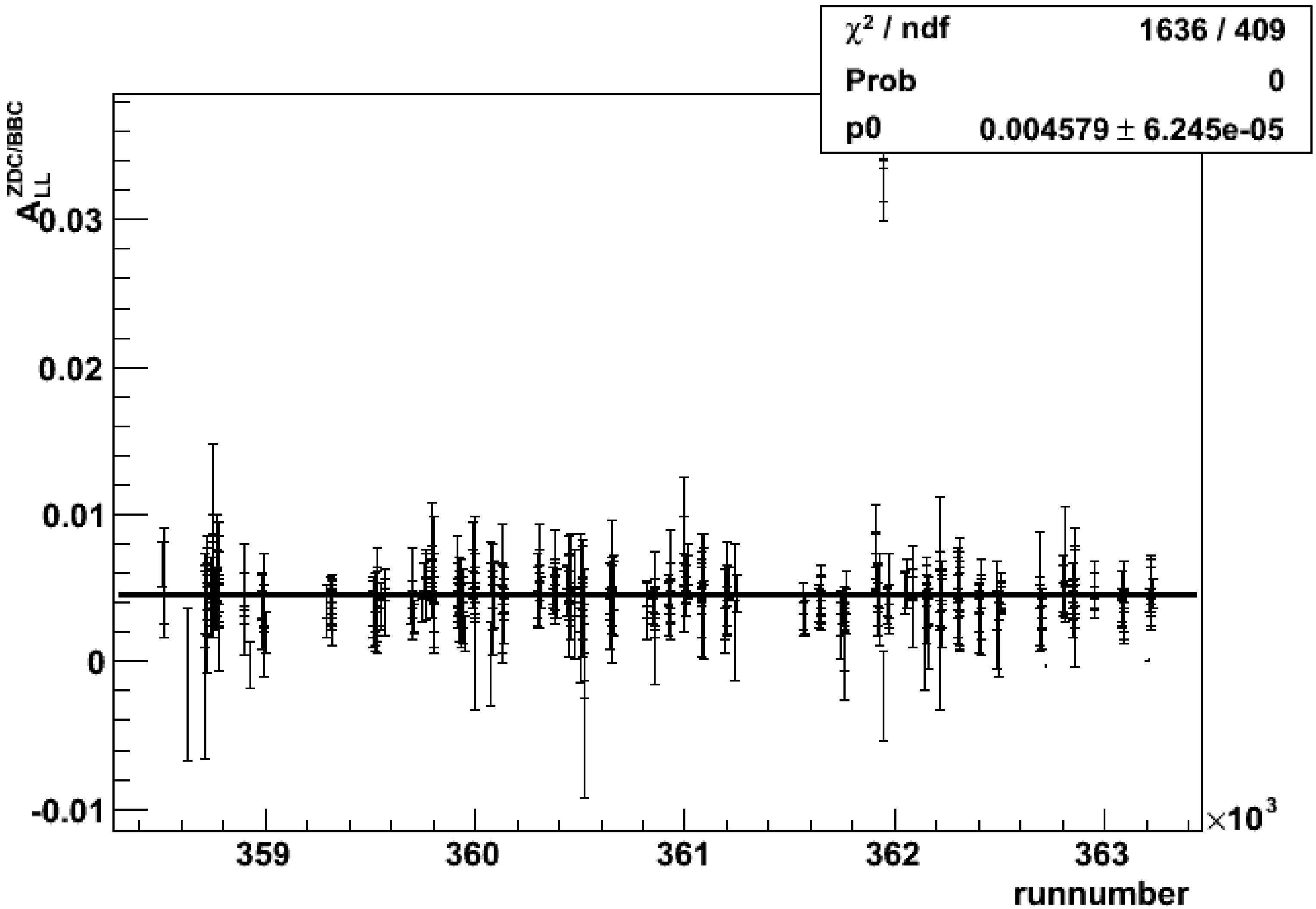
- However, now with Scott's residual correction, still get very bad ALL(ZDC/BBC)!
- Chi2 is vastly improved. Still, what is going on with ZDC/BBC ALL difference?

Run12pp200, No Corrections



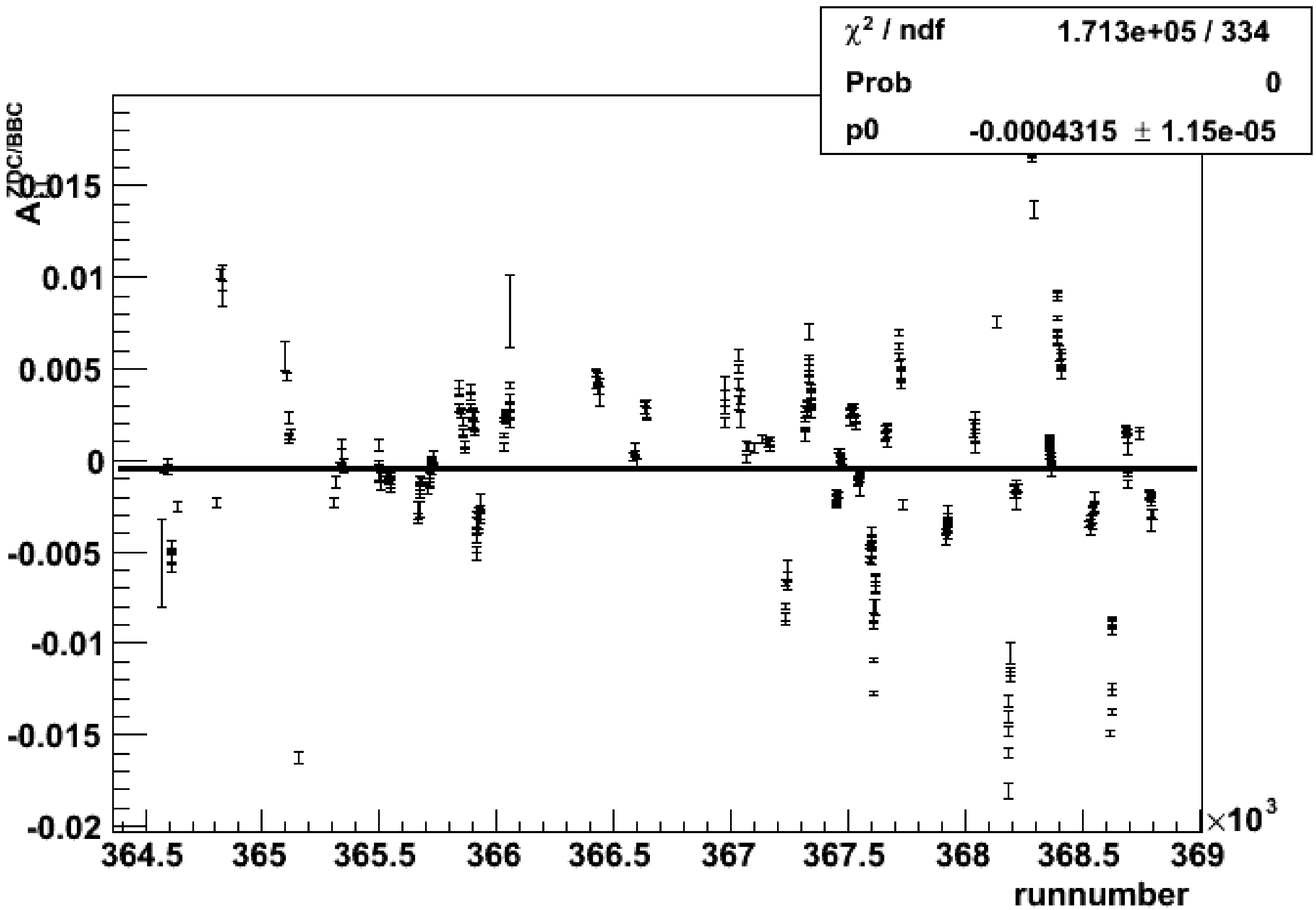
- Hypothesis was that maybe the noise in low rate run9pp200 was the problem, so I looked at run12pp200, where rates were higher
- Now uncorrected ALL(ZDC/BBC) ~ 46e-4!

Run12pp200 GL1P, pileup+zdc res

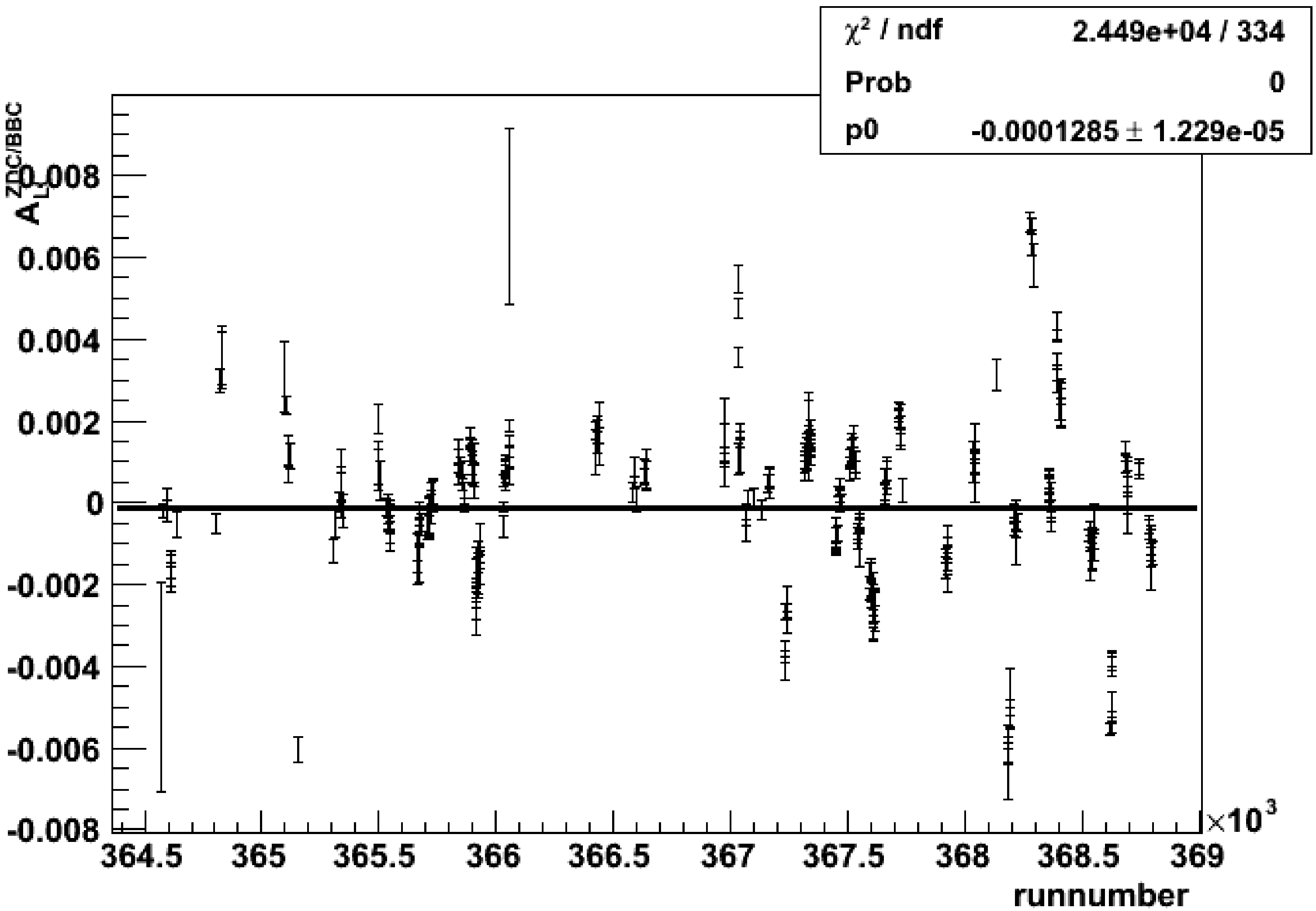


- However, after pileup and ZDC residual correction, still get 46e-4!

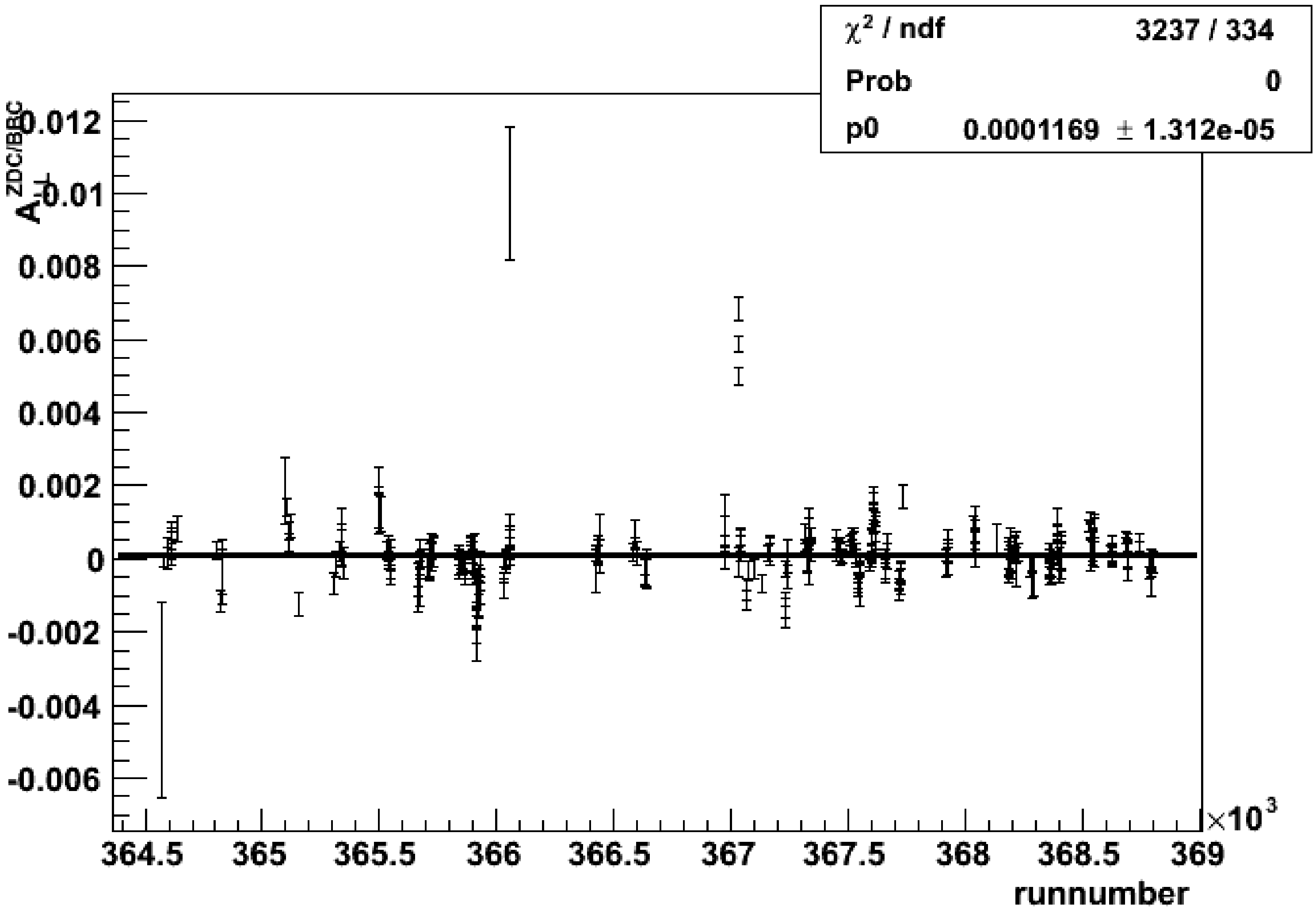
Run12pp500, no corrections



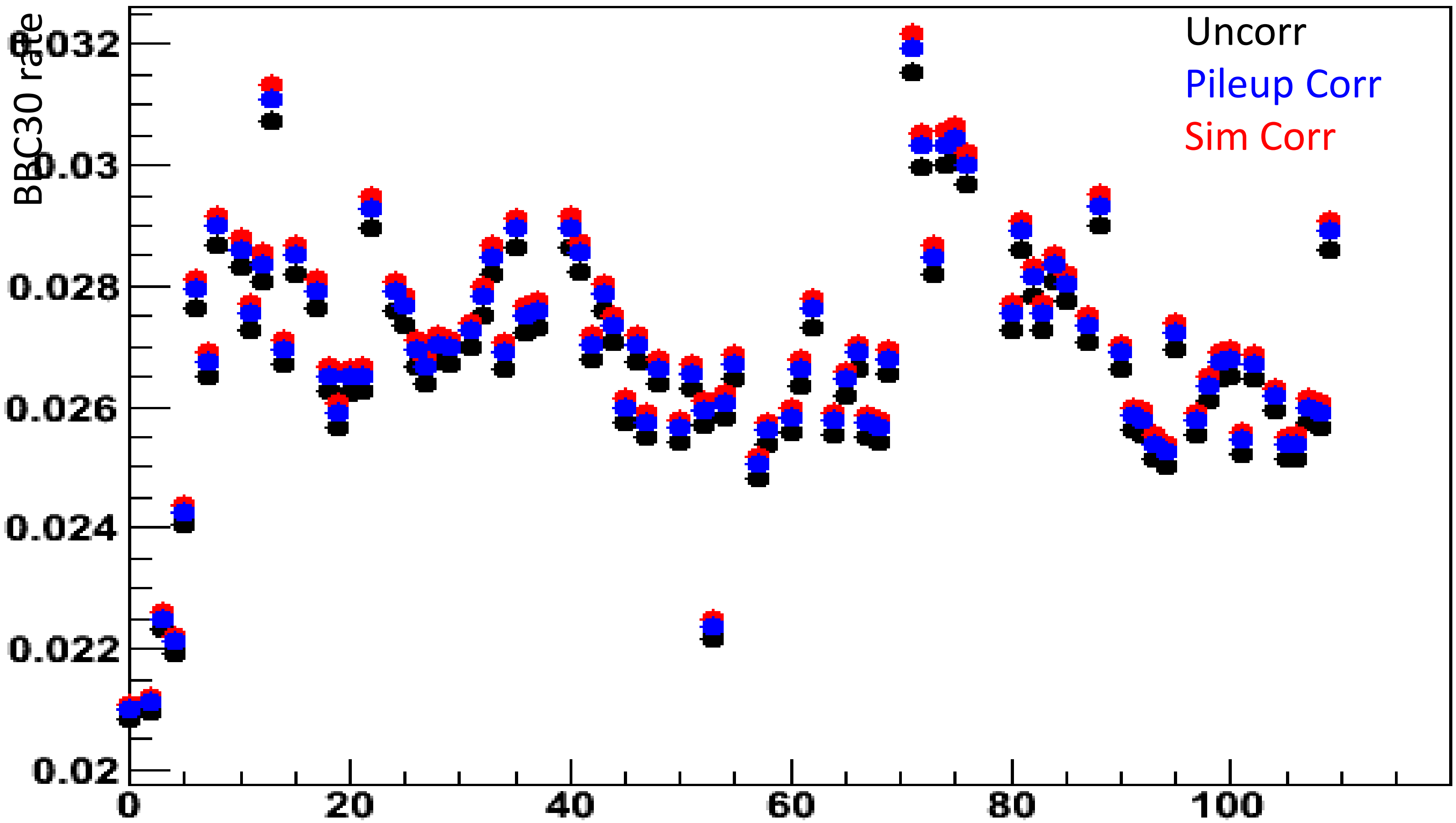
Run12pp500, pileup corr



Run12pp500, pileup + zdc residual

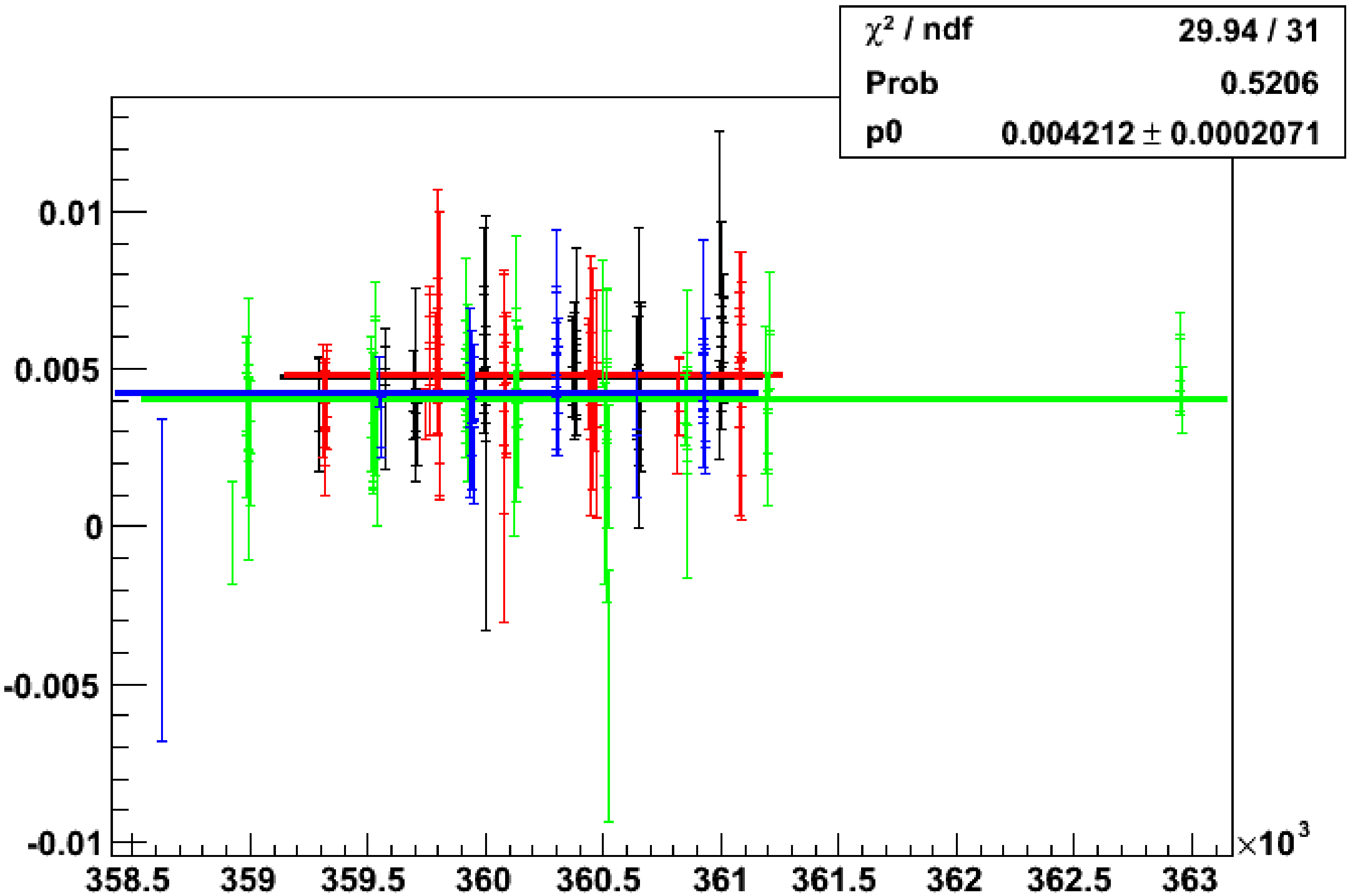


BBC30, pileup corr, and Full SIM true rates

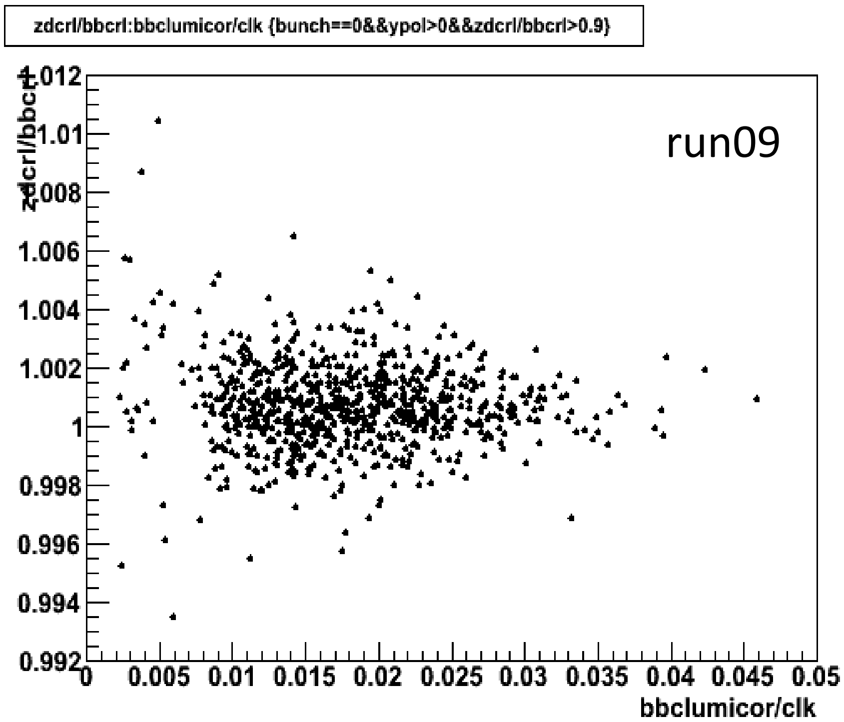


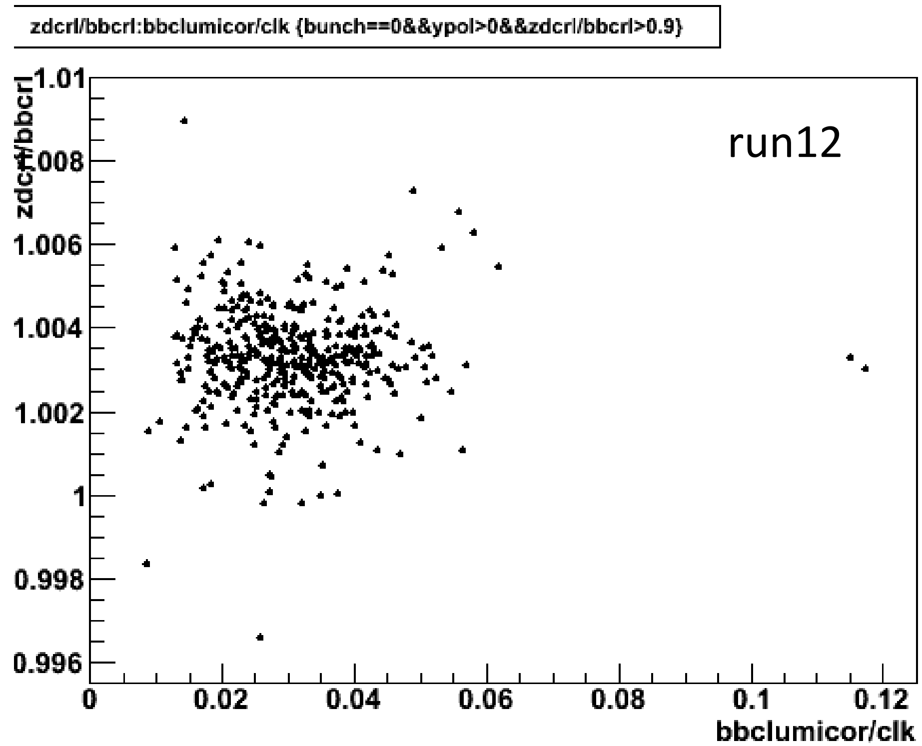
- The pileup corrections give a 1% correction, and the vertex cut in the trigger gives another 1%
- So the BBC does need to be corrected beyond just the pileup corrections.
- The additional correction is in line with Scott's analytic estimate.

Run12pp200, by spin pattern



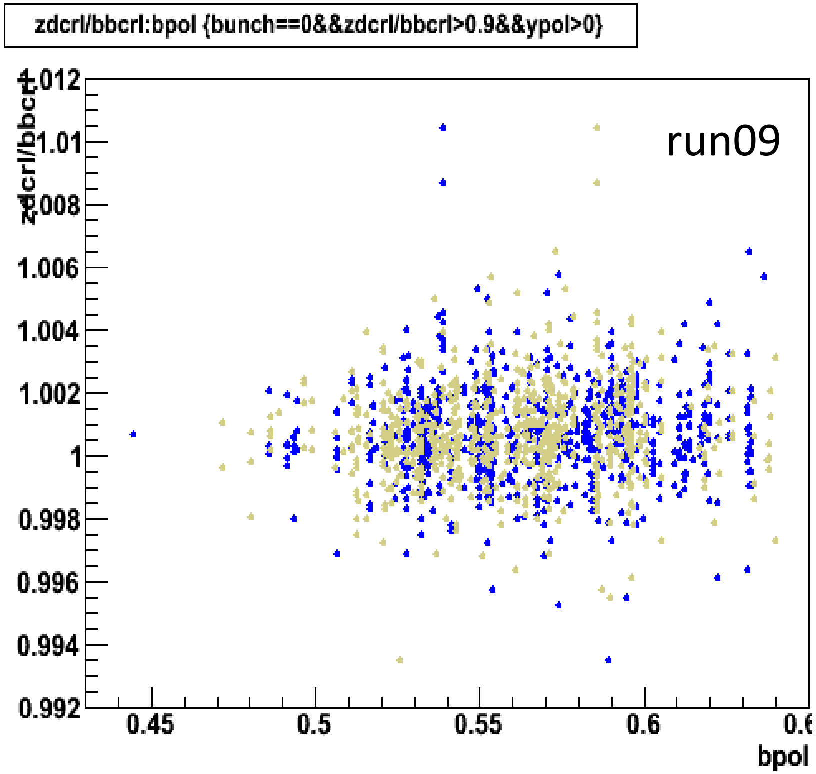
Rate Dependence?

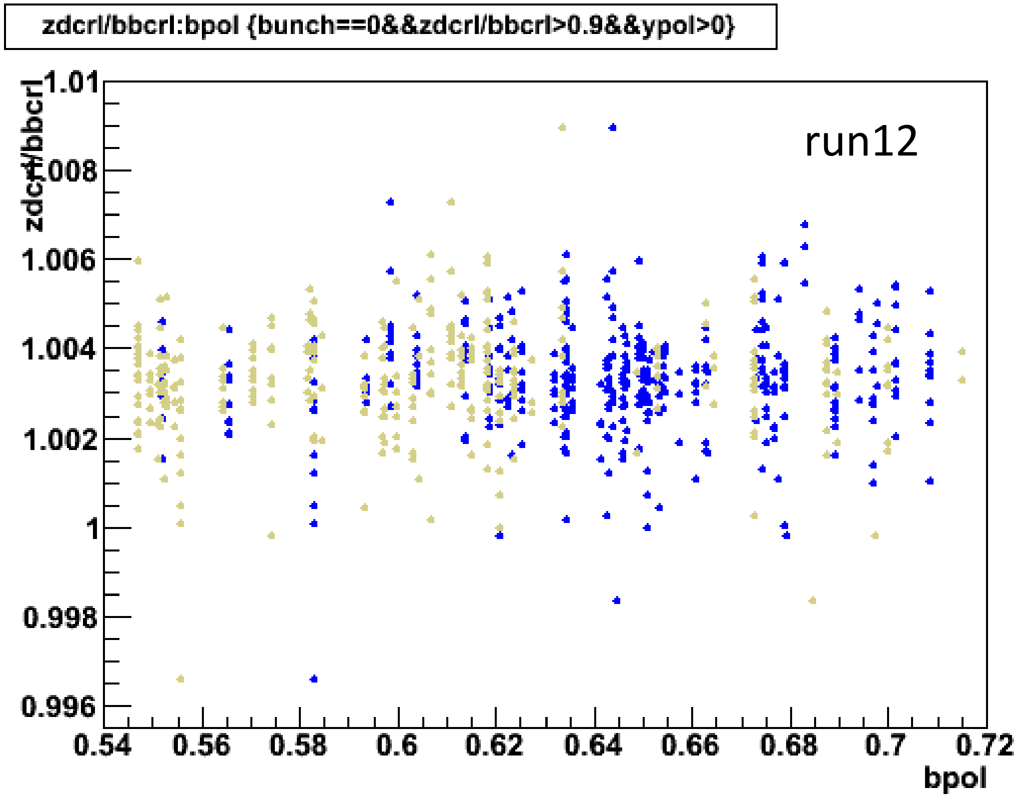




- Perhaps there is a rate dependent effect due to noise – at lower rates, the effect of noise (such as beam gas/beam scrape) is more prevalent.
- Don't seem to see it in the 200 GeV data… No strong visible effect.
- In particular, in the run12pp200, there is a large RL difference independent of rate.

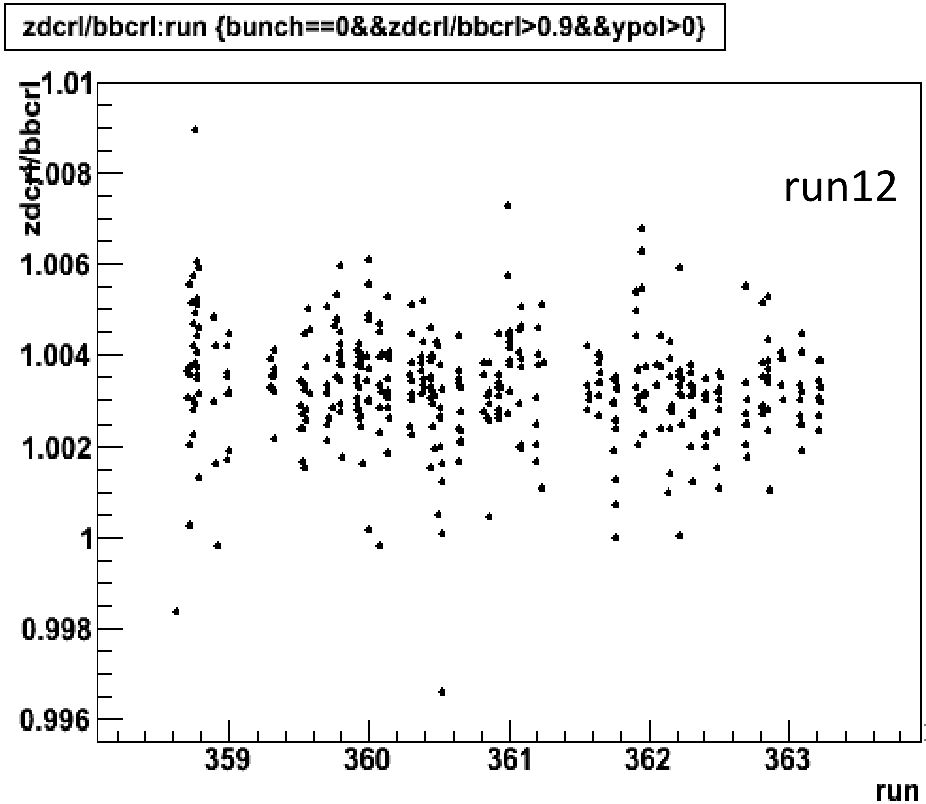
Polarization Dependent?

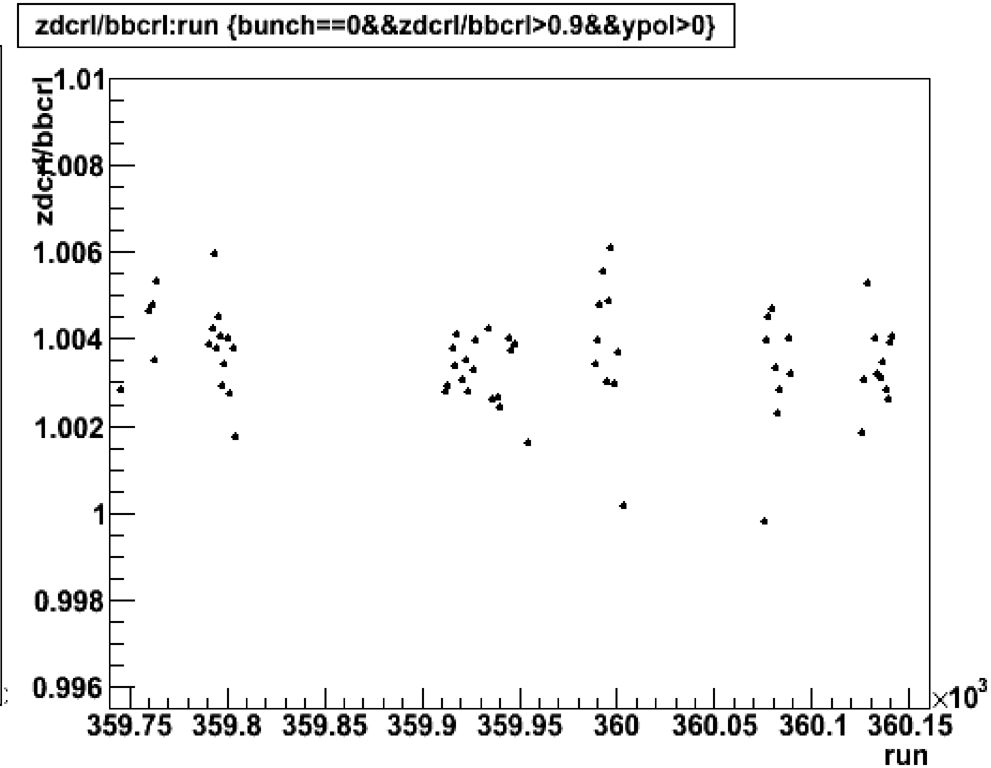




- Is it possible that it's a polarization effect? In run12 it was transversely polarized.
- However, we don't see a strong polarization dependence...
- Also, even within one run, the RL difference changes quite a bit, even though the polarization within a fill doesn't change drastically.

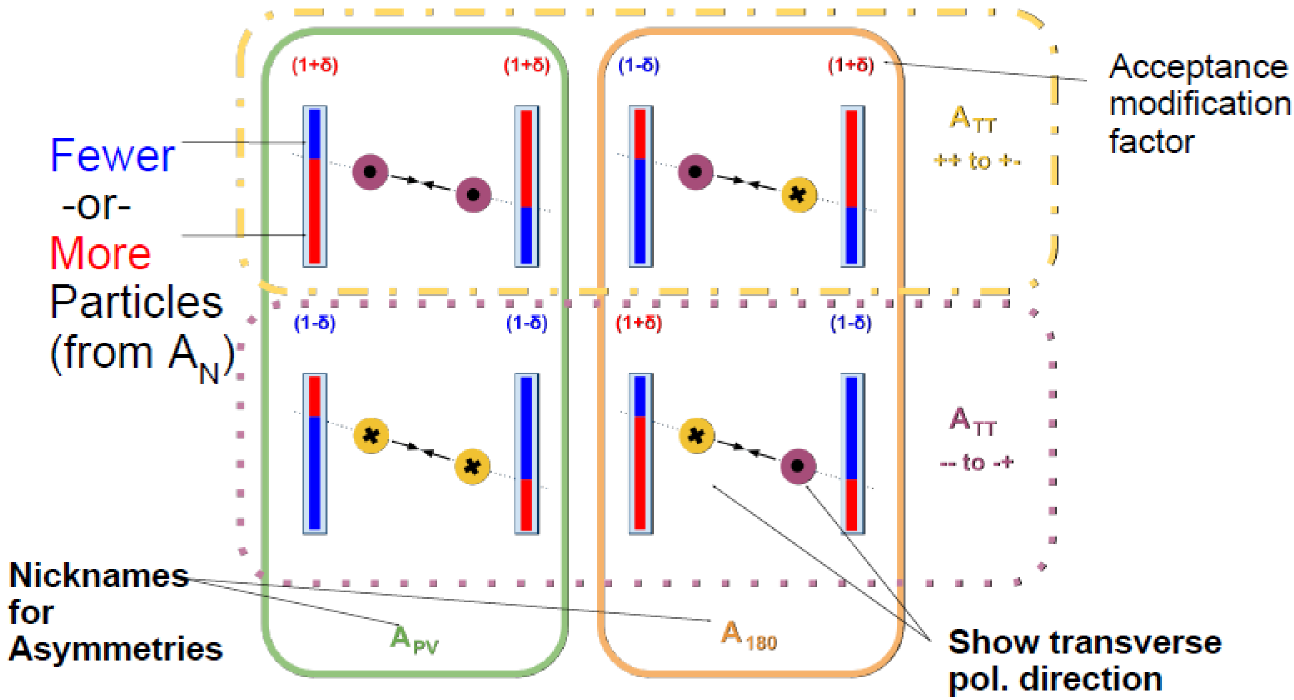
Time in Fill Dependence?





- Is there a dependency on when the run is taken within a fill?
- Doesn’t seem like it
- On right is a blow up of some runs within a fill

Rel-Lumi from Beam Angles and Offsets



- Acceptance issues due to noncollinear or offset beams are thought to also cause false asymmetries.

Relative Luminosity Summary

- Scalers to measure luminosity (BBC, ZDC)
  - GL1P, Star Scalers, (GL1, FVTX)
- Need corrections!
  - For pile-up effects
    - Rate corrections
  - Vertex cut in the trigger you scale
    - “Residual” correction
  - Vertex shape (efficiency differences with z-vtx)
  - Beam angles and offsets (small?)
  - Noise
    - Full simulation could possibly take care of all of these